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**JOURNAL OF  
THE ELISHA MITCHELL  
SCIENTIFIC SOCIETY**

**VOLUME FIFTY**

**IN COMMEMORATION  
OF  
THE FIFTIETH ANNIVERSARY  
OF THE  
FOUNDING  
OF THE  
ELISHA MITCHELL SCIENTIFIC SOCIETY  
AND OF  
THIS JOURNAL**

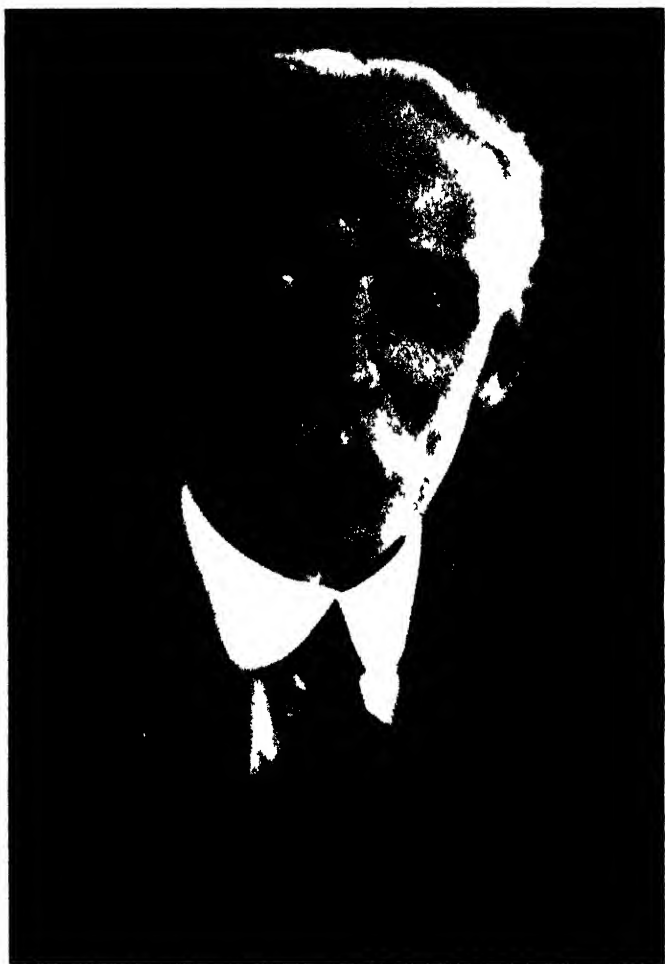
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## CONTENTS OF VOLUME 50

THE ELISHA MITCHELL SCIENTIFIC SOCIETY: ITS HISTORY AND ACHIEVEMENTS. <i>Archibald Henderson</i> .....	1
ADAPTATION: THE FOURTH PROPERTY OF PROTOPLASM. <i>Ivey F. Lewis</i> ....	14
PROCEEDINGS OF THE THIRTY-THIRD ANNUAL MEETING OF THE NORTH CAROLINA ACADEMY OF SCIENCE.....	21
PROCEEDINGS OF THE ELISHA MITCHELL SCIENTIFIC SOCIETY .....	56
GALLS AND "GALLS." <i>B. W. Wells</i> ..	65
CONTRIBUTION TO KNOWLEDGE OF NORTH AMERICAN FRESHWATER HARPACTICOID COPEPOD CRUSTACEA. <i>Robert E. Coker</i> ..	75
REACTION OF SOME FRESHWATER COPEPODS TO HIGH TEMPERATURES. <i>R. E. Coker</i> .....	143
MATHEMATICA PRAETERMISSA. <i>Archibald Henderson and John W. Lasley, Jr.</i>	160
A STUDY OF THE ACTION OF SODIUM SULFIDE ON POLYMETHYLENE HALIDES AND THE FORMATION OF "POLYTHIOPHANES." <i>R. W. Bost and M. W. Conn</i> .....	182
NEW NORTH AMERICAN SPECIES OF MAYFLIES (EPHEMERIDA). <i>Jay R. Traver</i> .....	189
TECHNIQUE IN THE PREPARATION OF COLEOPTERA. <i>J. M. Valentine</i> .....	255
RHYTHM, SYNCHRONISM, AND ALTERNATION IN THE STRIDULATION OF ORTHOPTERA. <i>B. B. Fulton</i> ..	263
ANATOMY OF THE TRANSITION REGION OF <i>HELIANTHUS ANNUUS</i> . <i>Albert F. Thiel</i> .....	268
THE DEVELOPMENT OF THE FRUITING BODY OF <i>ARACHNION ALBUM</i> . <i>Caroline A. Lander</i> .....	275
A TAXONOMIC AND MORPHOLOGICAL STUDY OF THE GENUS <i>CUSCUTA</i> , DODDERS, IN NORTH CAROLINA. <i>Budd Elmon Smith</i> ..	283
PUBLICATIONS IN THE FIELD OF SCIENCE FROM THE UNIVERSITY OF NORTH CAROLINA (1795-1934). <i>Alma Holland</i> .....	303



FRANCIS PRESTON VENABLE  
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Elisha Mitchell Scientific Society

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THE ELISHA MITCHELL SCIENTIFIC SOCIETY: ITS  
HISTORY AND ACHIEVEMENTS<sup>1</sup>

By ARCHIBALD HENDERSON

In his memorable essay, "The Literary Influence of Academies," Matthew Arnold points out that Richelieu, the great Cardinal, intended that the French Academy which he had founded in the second quarter of the seventeenth century should be a literary tribunal. Two centuries and more later Sainte-Beuve and Renan similarly interpreted Richelieu's intent: that the Academy should be a sort of "haut jury", a "sovereign organ of opinion" for creating a prevailing "form of intellectual culture." An academy sets a standard of the classical as opposed to the provincial, of the universal as opposed to the ephemeral.

Tonight it is my task to depict for you, in an all too brief moment, thirty minutes for fifty years, the history and achievements of a scientific society which, for a considerable period, played the rôle in North Carolina of a miniature academy of science. To paraphrase Matthew Arnold, I shall address myself then to the subject: "The *Scientific* Influence of Academies," as illustrated by the Elisha Mitchell Scientific Society. We shall see, I think, that this academy has likewise been a scientific tribunal, a medium for the discussion and dissemination of scientific theories and discoveries, for the canalization of scientific research.

The mind reverts to such great associations as the *Académie des Sciences*, which arose out of the meetings in Paris in 1629 of a bare handful of great thinkers: Descartes, Gassendi, and the Pascals, Blaise and

<sup>1</sup> Delivered in Gerrard Hall, University of North Carolina, Chapel Hill, N. C., November 14, 1933, in commemoration of the fiftieth anniversary of the founding of the Elisha Mitchell Scientific Society.

Étienne; of the "Royal Society for the improving of Natural Knowledge by experiments," the seeds of which were planted at Oxford University about 1648— a society which published the immortal *Principia Mathematica* of Sir Isaac Newton, the society's president for twenty-four years, until his death; and of the Preussische Akademie der Wissenschaften which arose out of the Societas Regia Scientiarum, constituted by Frederick I in 1700 on the comprehensive plan of Newton's great rival, Leibnitz. Some of the deeper impressions of my life abroad are derived from attending meetings of the French Academy, of the Institut de France, seeing the Academicians in their olive green uniforms and gold lace, with swords at their sides, and meeting such eminent mathematicians as Darboux, Painlevé, and Goursat; drinking in the memorable mathematical, physical, and astrophysical discussions of Sir J. J. Thompson, Sir Ernest Rutherford, Sir Arthur S. Eddington, Sir F. W. Aston, and Professor Fowler, a perfect nest of Nobel prize winners, at the Cambridge Philosophical Society; and thrilling to the vehement arguments of other Nobel prize winners—Einstein, Planck, von Laue, and Sommerfeld, at the seminars of the Physikalisches Institut of the University of Berlin.

Genius, energy, insatiable thirst for knowledge, and the passion for the discovery and disclosure of the secrets of Nature: these are the lofty, the immortal attributes of Mankind, which academies and scientific societies foster and promote.

Turn back with me now the pages of the Book of Life, to an event of no slight significance in the history of science which occurred in this little village of fifty years ago. Eight years earlier (1875) after a gloomy interregnum, the doors of the University had been hospitably swung wide once more. The total income of the University was less than \$20,000, the student body little more than 200. In the autumn of 1883 four professors of science—in the order stated in the original minute-book which I have personally examined—Professors F. P. Venable, J. A. Holmes, R. H. Graves, and J. W. Gore, issued an invitation for the purpose of organizing a scientific society to be known as The Elisha Mitchell Scientific Society. In addition to the four organizers, those who, on September 24, 1883, attended this first meeting, which was held in Professor Venable's house on Franklin Street, were: President K. P. Battle, Mr. W. B. Phillips, Dr. T. W. Harris, Mr. J. Manning, and Mr. E. A. de Schweinitz; and the meeting was presided over by the President of the University. The moving finger writes: time cannot blot out the names of Gore, Graves, Holmes, and Venable, grave scientists averag-

ing twenty-five years in age, all to achieve eminence in later years. Gore was head of the Physics Department here for many years, sometime Dean of the University, and indeed a sort of "universal dean," capable at any time of making the curriculum lightly jump through a hoop, roll over, and play dead. Graves, regarded as a profound thinker by his colleagues, was cut off too early to become widely famous as a mathematician. Holmes became State Geologist of North Carolina and later Director of the United States Bureau of Mines, which he created—the only one of all my colleagues whom I considered capable of filling the office of President of the United States; and Venable, who became one of the country's leading chemists and was some time President of this University.

I am glad to be able to read to you some portions of a circular which was sent out widely throughout the state following this first meeting of the society.

More thorough scientific training and increased interest in scientific work is a clearly felt want in the State. The building up of a true spirit of scientific research cannot be effected all at once, but it is believed that the formation of a Scientific Society, thus bringing about a union of strength and effort, will aid greatly in increasing the zeal of those already at work and arousing the interest of others. We have thought it well then to send out this plan of organization of such a Society, hoping to enlist in the Cause those to whom this paper is sent.

No more appropriate name could be chosen than that of the "Mitchell Society." If the Society flourishes it will be one of the few memorials left of that great worker at the scene of his labors. It is a name that breathes a spirit of indefatigable zeal, patience and perseverance—a spirit that must be emulated if this undertaking is to be carried out to success.

The *Objects* of the foundation of the Society are:

- 1st. The cultivation of an interest in Natural History and general scientific subjects.
- 2nd. The encouragement of individual workers, who isolated as they are at the present, with no one of congenial pursuits to turn to for advice or encouragement, are apt to become disheartened or indifferent and give up their work.
- 3rd. Increased knowledge of the State and its resources.
- 4th. Building up of smaller local societies.
- 5th. Collection of specimens.

The Plan of Working is as follows:

1. A small fee is to be paid by each member (say \$2.00) for the annual publication of a Journal to contain papers from members.

These papers are to be on original researches, new observations or facts collected—as for instance—reports of experiments carried



out in any branch of Science, observations on storms, strange growths, animal or plant life histories, collection of facts as to minerals, climatology, flora, and generally interesting statistics.

2. The publication of names of members, occupations, addresses, and scientific work accomplished.
3. At the center of the organization—the University—a series of lectures, popularizing science as far as possible—making its branches attractive, and explaining methods of observation.<sup>2</sup>

These ardent young scientists, aflame with the zeal for research, demonstrated their authenticity by the immediate establishment of a scientific journal entitled "The Journal of the Elisha Mitchell Scientific Society" which, during the past half-century, has made this institution famous the world around. These scientists were animated too by a deep devotion to this region and a will to labor unremittingly for its advancement. In the first presidential address, delivered on November 10, 1883, Venable earnestly voiced such an ambition:

This society wishes to play this part for the young men of this State, to take them by the hand and lead them in Nature's paths, to arouse in them an ardent purpose to know more of this grand creation and go on learning more and more until desire is stilled at last in the perfect light.<sup>3</sup>

The choice of a name, and a patron saint of science, for the Society was a happy one. I feel a real though intangible bond with the versatile Elisha Mitchell, who began his scientific career as professor of mathematics here; who had a son-in-law, Dr. J. J. Summerell, the father of the author of "Old Days in Chapel Hill," Hope Summerell Chamberlain, and our beloved friend and family physician; who preached his last sermon at Salisbury, my birthplace; and who lost his life while engaged in making barometrical observations over the same mountain region which I have assisted in mapping with stadia measurements and aneroid barometer for the United States Geological Survey.

Lineal descendant of the Rev. Jared Eliot, the distinguished natural philosopher, correspondent of Dr. Franklin and Bishop Berkeley and gold medalist of the Royal Society, Elisha Mitchell was himself a natural philosopher of eminence. It is an arguable question whether the chair he occupied here for almost forty years was a sofa, a davenport, or a settee. A graduate of Yale, where he was for a short time a tutor in

<sup>2</sup> This appeal, so far as I can discover, has never hitherto been printed, save as a circular. It does not appear in the published Journal of the Society. It appears in the secretary's manuscript records of the Society.

<sup>3</sup> North Carolina University Magazine, vol. 3, January, 1884.

mathematics, he succeeded Dr. Caldwell, on his elevation to the Presidency in 1818, as Professor of Mathematics and Natural Philosophy; and seven years later succeeded Dr. Denison Olmsted, who was called to Yale, as Professor of Chemistry, Geology, and Mineralogy. It must be borne in mind that he grew up with some of these still youthful sciences, which were developing as he taught them; and he wrote and published useful texts in natural history, chemistry, geology, and geography. He was active as a botanist, surveyor, road-builder, and agriculturist; and performed countless duties as regular preacher, professor, acting president, bursar, town commissioner, and magistrate of police.

On one occasion, when he was to deliver an address before the North Carolina Agricultural Society, a friend exclaimed: "I'll bet Dr. Mitchell begins at the Garden of Eden." And so he did—beginning in the Garden of Eden, passing through Egypt and Canaan, Greece, Rome, and Great Britain, and cheerfully ending up in Chatham County, North Carolina.

A man of culture, both wide and deep, he was an Admirable Crichton indeed—publishing some scientific articles in Silliman's Journal, but chiefly making popular scientific contributions to the State newspapers. The results of his scientific expeditions to the mountains of western North Carolina were sometimes embodied in long letters to his wife, sometimes in reports which were published.<sup>4</sup>

In 1794 the French scientist Michaux, the elder, climbed Grandfather Mountain, jubilantly sang there *The Marseillaise*, and later recorded his conviction that this peak was "*la plus haute montagne de toute l'Amérique Septentrionale*." John C. Calhoun in 1825 assured young David L. Swain, then a representative of Buncombe County in the State Legislature, that in that county must be located the highest mountain peaks on the continent east of the Rocky Mountains since here were found the sources of the longest rivers in the United States east of the Rockies: one of the great tributaries of the Mississippi, flowing into the Gulf of Mexico; the Kenhawa, entering the Ohio; and the Santee and Peedee, emptying into the Atlantic Ocean.

The crowning achievement of Elisha Mitchell's life, an achievement which this martyr to science won at the cost of his life, was the accurate measurement of the mountain which now bears his name. He was the first person to demonstrate scientifically that Mount Mitchell is actually

<sup>4</sup> Consult, for example, "Diary of a Geological Tour by Dr. Elisha Mitchell in 1827 and 1828, with Introduction and Notes by Kemp P. Battle, LL.D." James Sprunt Historical Monographs, No. 6, 1905.

the highest peak east of the Rockies. I wish to point out a memorable proof of his scientific accuracy: that the mean of his two observations of the height of Mount Mitchell is 6690—exactly (within 2 feet!) the figure (6688 feet) arrived at in the later determination of the United States Coast Survey. The figure, given by the more accurate methods of today, as surveyed by Professors Turner and Wilson is 6711 feet. In 1857, Dr. Mitchell, while making a final verification, lost his life through a fall in these rugged mountains, and at the request of the people of Buncombe County his remains are interred on the summit of the mountain which bears his honored name. Three successive monuments have been erected there in honor of Elisha Mitchell.

Before leaving this subject, I venture to propose the following projects for due consideration by the Society: (a) the securing of oil portraits of Elisha Mitchell and other distinguished scientists of this University, after the fashion of other great universities in this country and abroad, to hang in the University Library and in other suitable locations; (b) the establishment of a scientific museum where may be placed on perpetual display objects of enduring interest: scientific apparatus, inventions, pictures, rare books, manuscripts and correspondence, pertaining to the scientific activities of the University from its very foundation. The inspiration and stimulation they afford will furnish a powerful auxiliary of incalculable value to the activities of this society and of the scientific departments of the University.

The Elisha Mitchell Scientific Society was, on reliable authority, the first society of the kind established in connection with any southern university and among the first of those connected with any university in the United States.<sup>5</sup> I shudder to think of the retardation of science here and elsewhere had the Mitchell Society not been founded in 1883 and did not exist today. As I look around at so many monohippic institutions of so-called higher learning in the South and see their unchanging preference for the ideas of Wade, Warner, Zuppke, Haughton, and Bezdek to those of Michelson, Millikan, Richards, Compton, and Thomas Hunt Morgan, I shudder once more for the evanescence of the glory that was Rockne and the grandeur that was Stagg. Truly Irving Cobb was right when he said that all North Carolina needs is a press-

<sup>5</sup> It is interesting to record that an earlier scientific society in North Carolina was The Historical and Scientific Society of Wilmington, N. C. The second lecture, "The Nebular Hypothesis," was delivered before this society on April 5, 1882, by E. S. Martin. It was published by order of the society (Wilmington, N. C.: S. G. Hall, Book and Job Printer. 1882.).

agent. Thank God! science needs no press-agent. But only a couple of years ago I read an essay entitled: "The South's Contribution to Science";<sup>6</sup> and smiled with the wrong side of my mouth when I saw that there was no mention of Elisha Mitchell or of this Society; nor of Venable, Gore, Holmes, and Graves, the founders of this Society; nor of Olmsted, Gatling, Curtis, Croom; none of Lewis, Plyler, Cameron; there was mention of Baskerville but not of W. C. Coker; of R. E. Coker but not of H. V. Wilson; of the speaker but not of William Cain; of Manning but not of MacNider; of Herty but not of Stuhlman! Truly are North Carolina scientists, in the great ocean of present-day publicity, even as recorded in so reliable a journal as *Science*, "*rari nantes in gurgite vasto*."

Prior to the founding of this Society, the scientific activities of this university, while chiefly of a pioneering character, were of no mean order of excellence. Although limited in number, and in no sense comparable to the impressive productivity of the last half century, they stand out as not unworthy of an institution of this size and rank. We recall, in particular, the text books of Caldwell, Olmsted, Mitchell, James and Charles Phillips; the notable researches of Hentz, the highest American authority of his day on spiders; the geological and mineralogical reports of Olmsted and Mitchell, the former being, it is believed, the first published report of any State Geological Survey in the Union; and the erection here, in 1831, of the first astronomical observatory in connection with any institution of learning in America. I venture to express the hope that scientists and alumni of the University will earnestly seek to regain the lost astronomical opportunities of a century ago, and interest some wealthy philanthropist and friend of higher education to build here another astronomical observatory in conformity with the more stringent needs of the twentieth century.

During the lifetime of this Society, which has stimulated the reading of thousands and the publication of hundreds of papers and scores of books and monographs, the flood of published work has been so voluminous and tumultuous as to inundate the luckless scribe. (See bibliography, p. 303.) In 1910 was published a lengthy report, entitled "Scientific Investigation at the University: 1795-1910." Voluminous as are the scientific activities of the University for the twenty-seven years from 1883 to 1910, they are perhaps ten times as voluminous for the twenty-three years from 1910 to 1933. The mere reading of the titles at a leisurely rate of speed would consume several hours; and it is impossible to compute the number of decasyllabic and sesquipedalian technical

<sup>6</sup> Emmett B. Carmichael. *Science* 74: 421. 1931.

terms which would indubitably be shockingly mispronounced by the speaker. In face of this unconquerable army of obstacles, I cry "Kamerad"; and beg to compromise by reciting, all too briefly, without mentioning the scientists by name, the major lines of research. Before embarking upon this sea of troubles, may I recall to your mind two interesting remarks made by well-informed observers. One is that it is impossible to throw a brick in any region where members of this faculty congregate without hitting a person who has recently published a book. The other is that the University of North Carolina, on the basis of size, is the most productive center of creative and critical activity in this country, if not in the world. One word of my own: I salute tonight, in this presence, two great scientists, professors emeriti of this university, one who tragically mislaid, almost casually lost his life before his own doorstep, the other still honored and revered in the land of the living: William Cain and Francis Preston Venable. The latter until his retirement, after fifty years of service here, the former for ten years after his retirement even unto the day of his death at the age of eighty-three: both continued with unabated ardor if with somewhat flagging strength that unending quest of the unknown, that pursuit of the Gleam of God's Truth, which makes the scientist of the noblest of mankind. I salute them: *Par nobile fratrum*.

Let me then, in conclusion, attempt, all too inadequately, to traverse the *major* lines of research only, pursued in the various scientific departments here since 1910, leaving for the formal bibliography (cited above) the task of identification of the individual authors. The magnitude of certain of these researches, occupying great treatises, government monographs, and superb papers, many of them magnificently illustrated, cannot be conveyed or even indicated by a bare recital of descriptive titles.

In *Botany*, far ranging studies in the higher fungi (mushrooms) involving the discovery of many new species, and systematic and morphological study of particular groups: the Clavarias of the Eastern United States and Canada, the Gasteromycetes ("puffballs"), the gill fungi in North Carolina and the eastern United States, and the Septobasidiiums of the world, first evidencing the true symbiotic relationship between this group of fungi and scale insects; and in the lower fungi, especially water-molds, comprehensive studies of the Saprolegniaceae, the genus *Pythium*, sexuality in *Dictyuchus* (a modern touch), parasitic forms inhabiting water; among the higher plants, studies of the trees of the southeastern United States and the flora of North Carolina; the collection of

classical works in botany and manuscripts, correspondence, and other rare data concerning southern botanists: De Schweinitz, Curtis, Ravenel, Gattinger, Elliott, Chapman, Mohr, and Porcher.

In *Chemistry*, an imposing series of individual studies too numerous to catalogue, including: a new determination of the atomic weight of zirconium, equilibria conditions in systems composed of the nitrotoluenes; the preparation of many new dyes from studies in the chemistry of Para-cymene, intensive researches into the properties of dihydroxynaphthalene and juglone; numerous applications of the technic of "pure" science to the investigation of many industrial problems, notably those pertaining to iron, copper, salt, rubber, and cellulose and its derivatives from cotton; studies of the acids, and paper coatings of the alum type; theory of solutions, revealing new mathematical relationships, conductivity measurements, phase rule studies, thermal properties of organic compounds; studies of organic and metallic compounds, notably of tin, lead, and sulphur; and studies in agitation (for which I personally am now a fit subject), with reference to mixing and stirring.

In *Engineering*, the contributions fall into several categories. In *Highway Engineering* a notable series of experiments from 1923 to 1929, in coöperation with the United States Bureau of Public Roads and the North Carolina Highway Commission, were conducted here, for determining the effect of capillary moisture on drainage and earth pressure, to obtain data for use in the design of highway culverts. New methods have been devised for laying out highway curves, including easement curves, both horizontally and vertically; and pioneer work in the application of scientific principles to the design, location, and construction of roads and bridges.

In *Hydraulics and Hydrology*, extended investigations regarding aqueous problems: rainfall, stream pollution, floods, evaporation, water powers, coastal erosion, and structural designs for preventing coastal changes—many of these investigations carried on in coöperation with the North Carolina Department of Conservation and Development.

In *Municipal and Sanitary Engineering*, detailed studies of methods of treating sewage and trade wastes, especially in connection with the municipalities of Durham and Chapel Hill.

In *Electrical Engineering*, contributions to the development of multiplex radio communication, investigations of television reception and transmission, and studies of the performance curves of polyphase induction motors on unbalanced impressed voltages.

In *Mechanical Engineering*, contributions have been made on the

response of thermocouples to temperature variations, the measurement of surface temperatures, and in aeronautics the effect of streamlining the under-portions of automobiles and development of apparatus for measuring air velocities with pulsating flow.

In *Structural Engineering*, notable contributions were made over a long period of years dealing with earth pressure, retaining walls, tunnels and bins, stresses in certain types of reinforced concrete beams; a new formula for the strength of columns, and a more exact design for continuous beams and columns, especially in tall building frames, with a new definition for the so-called stiffness and degree of fixation of a member. The most notable perhaps of these contributions was the elaborate monograph, "The Circular Arch under Normal Loads," by the late Dr. William Cain, then professor emeritus, for which in 1923 he was awarded by the American Society of Civil Engineers the J. James R. Croes gold medal.

In *Geology*, the major contributions have been in the following fields: human geography and loessal geology of China and the Mississippi Valley; economic geology of coal, graphite, and marble; Silurian stratigraphy and Triassic structure and stratigraphy; economic geology and mineralogy; structural and sedimentary geology; and Devonian stratigraphy and mathematical geology.

In *Mathematics*, extended studies have been made in the theories of Einstein known as Special and General Relativity, with particular reference to the conceptions of a finite, unbounded universe and the expanding universe; higher and especially cubic surfaces; investigations in the field of modern higher algebra, dealing with the linear transformation and the matrix, linear classes of involution in hyperspace, the signature of a quadratic form; in the field of Differential Geometry the curvature of manifolds, and properties, metric and projective, of certain special classes of curves, congruences, and surfaces; fundamental problems arising in the field of Calculus of Variations; and numerous basic project-problems in the pedagogy of mathematics.

In *Medicine*, two phases of research deserve record here. Over a period of twenty-nine years in the Department of *Pharmacology*, extensive studies have been made of nephritis and other diseases of the kidney. Prolonged investigations of the changes in animals with induced acute nephritis resulted in the discovery of effective therapeutic discipline for protecting the kidney in pregnancy and for prophylaxis and to a lesser extent cure in bichloride of mercury poisoning. It was discovered that a balance between the acids and bases in the blood affords

the best functioning of the kidney, and further, that this balance could be preserved against the disturbance to the kidney of a general anaesthetic. This treatment was employed successfully in cases of "Trench" nephritis during the World War. Study of the successive changes in the kidney in progress to chronic nephritis has thrown considerable light on the causes of sudden changes and the ways in which the injured organs repair themselves. A new theory has been advanced, on the basis of twelve years of research, that kidneys which repair themselves by the development of a certain type of epithelium become capable of resistance to subsequent injury.

In the field of *Anatomy*, researches have been carried on regarding the pulmonary circulation in vertebrates and particularly in man; concerning the structure of the blood of Ascidians, a fertile field of research, since little is known concerning this biologically important group of animals; and broad inquiries into the philosophical significance of some of our physical and biological knowledge.

In the field of *Pharmacy*, the pharmacopoeia is so immense and the topics so varied that it is exceedingly difficult to disengage major trends of research. Comprehensive studies have been made of the distillation of oils, on soaps, and on the effect of fatty acids on emulsions and liniments; important reports on drug reform and the new pharmacopoeia and surveys of present-day pharmacy; discoveries regarding medicinal and curative properties and the therapeutic action of various plants, drugs, extracts, chemicals; many contributions on the public, historical, professional, legal, and ethical aspects of pharmacy; and lastly the never-to-be-forgotten paper of the late Professor Vernon Howell on alcohol as an antidote for carbolic acid, which, because of Professor Cobb's alarming experience, is uniformly spelled in Chapel Hill, "Cobbolic" acid.

In the field of *Physics*, the problems treated have been the subjects of prolonged research and lend themselves more readily to enumeration. Over a period of ten years (1920-1930) a major problem studied was the inverse photoelectric effect; and separate studies were made of X-ray localization, phosphorescence, thermophosphorescence radiations, and tables for the ionization of gases. Later researches deal with the electrodeless discharge of gases and resulting intensity of spectra. Extended researches have been made on infra-red absorption spectra, particularly in regard to the absorption of solids, liquids, and gases. New relations and properties were discovered, notably: analysis of the molecular structure of water vapor and nitrous oxide; a new classification of the band types for organic liquids; and a relationship between the absorption spectra and the crystal structure for quartz, calcite, and ice.



In the field of *Psychology*, the major problems of research happily fall into a three-fold classification: clinical, theoretical, and experimental. Studies are made all the way from man, in normal, emotional, neurotic, and psychotic states, to the white rat which, however uncomplimentary to man, is always presumed to be in the normal state. Clinical studies have been made here on the campus and throughout the state, in and out of hospitals, of human beings in various states of difficulty, emotional, social, mental. New theories, alternative to those of psychoanalysis, concerning certain basal interpretations of the milder emotional abnormalities have been developed. Intensive studies have been made of the more technical methods of psychometrics and mental examination, and a radical improvement of the case-history technic devised. New interpretations of perception, of the thought-processes, and of emotions in human beings have been advanced. In the experimental division, ingenious investigations on the nature of animal learning have been carried on, pointing to the rôle of some hitherto overlooked factors, notably direction-orientation. Constructive studies in human habit-formation have been made, as well as experimental analyses of social situations, including some of legal importance. In this age of pitiless publicity, it is noteworthy that some new points of technic have been developed in the experimental psychology of advertising.

Alphabetically last but in the front rank in quality, significance, and technic is the research work of the department of *Zoology*. Without cessation have appeared papers and monographs occupied with the classic classification of sponges; wide-ranging studies in the embryology of fishes and amphibia; cellular behavior in the regeneration of sponges, hydroids, ascidians, and in the clotting of the lymph of sea urchins. Comprehensive studies have been made in the classification and natural history of fresh water copepods and the influence of environmental conditions on size, form, and physiology of small crustacean animals; and general investigations of the biology of fish. Much has been learned concerning the genetics and general physiology of the protozoa, modification of the life cycle through changes in dietary and other factors, conditions under which the dormant phase known as encystment occurs, and feeding habits—even under the depression and the NRA. Nor have been neglected the humble cave beetles, their variation and classification as indicating their evolutionary history.

I am happy to offer you, through the courtesy of the University Librarian, Mr. Downs, and Miss Thornton, Curator or Curatress of Caroliniana, an exhibit tonight here in this hall of scientific works of

value and importance, ranging over the first half-century of the University's history. Here is Joseph Caldwell's *A New System of Geometry*, in manuscript form, transcribed by Edward McKay, 1806; and this same work of Dr. Caldwell's, greatly extended and in printed form (Philadelphia, 1822): "A Compendious System of Elementary Geometry, in seven books, together with a Treatise of Plane and Spherical Trigonometry." Here are Professor James Phillips's "The Elements of the Conic Sections" (New York, 1828) and Professor Charles Phillips's "Manual of Plane and Spherical Trigonometry" (Raleigh, 1857). Here are Elisha Mitchell's "Elements of Geology with an Outline of the Geology of North Carolina for the Use of the Students of the University" (1842) and his printed syllabus on "Natural History." Here are Professor Olmsted's "Outlines of the Lectures on Chemistry, Mineralogy and Geology delivered at the University of North Carolina for the use of the Students" (Raleigh, 1819); and the first report, in three parts, by Professors Olmsted and Mitchell, of any State Geological Survey in the United States (1824, 1825, 1827). And here too are numerous melancholy mementos of Dr. Elisha Mitchell and his tragic death: his gold watch, stopped at 18 minutes past 8 o'clock, the moment of his decease, in that precipitous fall; the last letter he ever wrote, from "Patton's Mountain House," in which he spoke of the very mountain journey on which he a few days later lost his life; photographs of Mount Mitchell, of the three monuments to Dr. Mitchell, of Big Tom Wilson, who discovered his body, and last of all a copy of the *Chapel Hill Gazette*, of July 13, 1857, announcing his death—deeply bordered with mourning bands. May I not quote in conclusion the lines of General Robert Vance:

On the highest peak of a mighty chain  
Of hill and mountain fastness,  
Where Nature doth her primal rule maintain  
Amid their solemn vastness,  
There's a lonely grave that the mountain gave  
Which the sorrowing moonbeams gently lave.

\* \* \*

But a morn shall come, O glorious morn!  
When the trumpet's shrill sounding  
Shall reach every soul that ever was born  
And life anew be bounding;  
And God in His might, from the mountain height,  
Shall wake His servant to the wondrous sight.

## ADAPTATION: THE FOURTH PROPERTY OF PROTOPLASM

By IVEY F. LEWIS

Just one year after the death of Charles Darwin the Elisha Mitchell Scientific Society was founded at the University of North Carolina. It has seen the University grow from its second infancy through the period of struggle for survival under Battle, the first growing pains under Winston, the steady progress under Alderman, the establishment of a bed-rock tradition of scholarship under Venable, the rapid growth in public confidence under Graham, the swift expansion under Chase to the present regime of Frank Graham, when as the Greater University it enters upon the next phase of its great destiny. When I was a student here, the favorite motto was "*Per aspera ad astra*." It might well be the University's motto, for it epitomizes the history of this old institution, out of whose struggles has come the will to serve the state and nation with ever increasing distinction.

The Society, too, must have had its moments when the will to carry on had a flavor of grimness, for I recall that one secretary, hard pressed for something to fill up his program, asked me to appear and present a paper. I have never forgotten the shock to my modesty when I realized at the last fatal moment that I must speak before Wilson and Venable, Cobb and Baskerville and Gore, who claimed then my adolescent hero worship and for whom my respect and affection have continued through the years.

When the Society was founded, the Origin of Species had come of age and Biology had been unified by the acceptance of protoplasm as the physical basis of life. I believe this was the greatest advance in biological thought in the nineteenth century. The generalization of Schulze had been presented to the world by Huxley in his great essay, "The Physical Basis of Life," and had become the central fact of Biology. You will recall that Huxley in defining protoplasm characterized it as possessed of three unique properties, which mark it off from the non-living under all circumstances. The first of these is its unique chemical composition, the second its power of waste and repair with consequent growth, the third the cyclical nature of its activities, birth, growth, maturity, death.

I venture to suggest that a fourth fundamental property may be added to these, a property from which Huxley shied as jarring upon his philosophy, but which is as real and demonstrable as any of those he stated. This is the power of adaptation, the power of developing structure or behavior which by the physical laws of chance are not to be expected, but which when developed contribute something of utility to the organism. There is an apparent purposiveness to adaptation, and this in itself would cause Huxley to look askance at it. He saw the dull futility of explanations couched in terms of purpose, especially if in the language of current theology this purpose was set, as it often was, in human terms. To explain nature in relation to man's need was a common way of thinking. The sunset was to uplift the human soul with beauty, the grain was to feed man, the horse to transport him, the mosquito was to keep him humble and develop his patience and good temper. Even the flea had a mission in life which was to keep dogs from worrying over the fact that they were dogs by giving them something else to think about.

Darwin, by reliance on the laws of chance, avoided all this. We should remember though that evolution as a theory has two objectives, not only to account for the origin of species and the great pageant of life through the ages, but also to give a caudo-mechanical explanation of adaptation, which so closely resembles purposiveness that the two may honestly be confused. Of these two problems, the origin of species is nearer a wide solution than adaptation, which remains at the present time the major biological problem in whose complexities the riddle of the universe may yet find its key.

Adaptations may be structural. Such an adaptation would be the tongue of a woodpecker, a stiletto sharp as a needle with recurved barbs, meaningless until you notice how it is used. The woodpecker, after cocking his head and listening, concludes that a beetle larva is at work under the bark of a tree. He whacks away until he opens the borer's tunnel, darts his long tongue in, transfixes his victim, and drags him out without having to chisel away the surrounding wood.

The goose fish is predacious, but without the speed necessary to run down his prey. He has a small body and an enormous mouth. Running back from his head and lying on his back is a long rod, at the end of which is a ragged tuft of reddish threads looking something like small worms. The fish can raise the rod and dangle the "worms" like bait in front of his mouth. The first minnow that comes along to investigate is a signal for the goose fish to open his cavernous mouth suddenly "and welcome little fishes in with gently smiling jaws."

A tiny fungus, belonging to the general group to our knowledge of which so much has been added by Coker and his students, was shown to me last summer at the Mountain Lake Biological Station of the University of Virginia by Dr. Couch. It was *Zoophagus*, which I had long wanted to see. At intervals along the hypha came out at right angles short needle-like spines on which were straight barbs. There was not enough of it or time was lacking for a thorough study, but it was a very striking fact that many of these spines were imbedded in the bodies of rotifers. Presumably these impaled themselves under the mistaken impression that the spines were edible. Actually it was just the reverse; the rotifers were edible, as the fungus digested their internal tissues.

A green plant rather common in ponds is the bladderwort, or *Utricularia*. This has on the finely dissected leaves small bladders of curious construction. There is a trap door set with a trigger. When the door is closed, the living cells of the wall pump out the water by osmotic forces, producing a negative pressure within. When a small aquatic animal touches the trigger, the door springs inward and the rush of water carries the bug along with it into the cavity. The dissipation of the negative pressure causes the door to close again, and then glandular cells on the inside of the wall secrete digestive juices as though the bladder were a little stomach.

Other adaptations are behavioral. Such is the behavior of the leaves which have been falling on the campus. Weeks ago, before there was any threat of frost, these leaves prepared for the crisis of winter by laying down an abscission layer of corky cells across the base of the petiole. This layer cuts cleanly across the living tissues, leaving the leaf firmly attached by the conducting bundles. The first frost causes a break, and the next puff of wind sends the leaf falling down, but leaving not a raw little scar where the break came but a cleanly protected bit of scar tissue, prepared in advance.

A somewhat similar adaptation is the attitude of bees to fire and to furry animals. Wild bees in the forest where they have lived for thousands of years have two great enemies to fear. One is the bear, which rips out the combs. Even the domesticated bee will launch a savage attack on an animal with fur. It is dangerous to let a horse come too close to a bee hive. The cautious bee keeper does not allow his beard to grow. Evidently, in some way the bee's behavior is conditioned by bee traditions based on experience in the past.

Similarly a bee reacts to his second great enemy, fire. At the first

smell of smoke every worker bee in a hive fills up with honey so as to save out of the holocaust something of his little fortune. The bee keeper uses this instinct. When he wants to handle his bees without getting stung he gives them a whiff of smoke. In the forest that would mean a forest fire which would force immediate flight, but the prudent bee stops first to save what he can and becomes so turgid with honey that he can hardly bend his little body into the stinging posture. In his structure and behavior the bee is prepared for his two greatest enemies in the natural or wild condition.

Another example of structure aided by behavior is the common *fumigatus* mold, *Pilobolus*. This occurs on horse dung, on the surface of which it raises its sporangia. Just under the sporangium is a swollen turgid bladder, the pressure in which becomes so great that it finally explodes, blowing the mass of spores off with great force. The spores, instead of being dry and powdery as in the related bread mold, remain sticking together in a gluey mass. This flies out at high speed and travels some feet before it comes down. It sticks to anything it touches. The *Pilobolus* points its sporophore at the source of light. "She turns on her God when he sets the same look that she turned when he rose." This orientation to light is very precise. If *Pilobolus* is put in a dark box and a pin hole made in the lighted side, the fungus can hit the hole with its spore ball with the precision of an old time tobacco chewer whose artistry used to fill me with admiration in the good old days.

This behavior can be understood only in relation to the mode of life of *Pilobolus*. It occurs normally where horses graze in pastures. Its spores do not develop except in dung, and germinate better if they pass through the intestine of a horse. By aiming at the sun, the sporophore attains approximately the right elevation to give a trajectory which will throw the spores the farthest, certainly well away from the mass of dung in which it grows. When the spore ball comes down it is likely to strike a blade of grass and stick to it. The horse then eats the grass, and the *Pilobolus* has succeeded in providing for its propagation and dispersal.

The rabbit shows some interesting adaptations. Its timidity, its ability to lie doggo, its sudden burst of speed when it breaks from its form, its twisting dash and final dart into a briar patch—all these things contribute to rabbit survival. On the western plains, however, these qualities would spell disaster. The jack rabbit is not so timid, does not remain to the last minute before running, and when he does run goes straight away at a high and sustained speed. The jack rabbit would

not survive on our Orange County hillsides, nor would the cottontail be able to make a go of it on the open plain.

The examples given have to do with protoplasm. In all cases living material is involved. To explain such adaptations there have been two great historic attempts, the first by Lamarck, which appeals to the layman with extraordinary force, and the other by Darwin, which is in better standing with the cognoscenti, but scorned or ignored by the biologically unwashed.

The Lamarckian theory is plausible because it has to do in part with muscular action, and everybody knows that use strengthens muscles. The reason why a rabbit runs fast according to Lamarckian doctrine is simply that he frequently needs to run fast, and this frequent use of his running muscles causes them to become powerful and has its effect on the race. The giraffe has an extraordinarily long neck because he feeds on the leaves of trees, and in reaching for them stretches his neck and even passes on the tendency to his children.

To Darwin, on the other hand, the rabbit runs fast simply because all those rabbits which did not run fast have long ago been eaten by foxes or hawks. There are no brave rabbits, though it is quite conceivable that some rabbits have a little more sangfroid and spirit of derring-do than others. It is not a healthy tendency, though, and the rabbits we now see are descended from the timid and inherit their timidity. Darwin postulates the survival of the useful, and bases survival on the totality of effect. Here his theory meets its greatest difficulties, because the totality of effect involves many characters in their interrelations. Darwinism assumes throughout random variations. Any quantitative variation is as likely to be plus as minus. Chances are one in two that a given variation will be on the favorable side.

Many adaptations such as speed in a rabbit or the length of the giraffe's neck are adapted to Darwinian reasoning and give verisimilitude to the theory, but there are some adaptations which are as inconceivable to the thorough Lamarckian as they are impossible to the pure Darwinian. Such a case is offered by the sporangium of a fern.

The fern sporangium is a helmet-shaped box containing spores. It has a ridge or sort of cock's comb of a single row of cells running nearly all around its edge except the point where the box will break open when conditions are right. There may be twelve or more of these cells in the annulus. Of the six walls, three are thin cellulose and three thick lignin. Lignin is a very tough elastic strong substance, while there is a good deal more of "give" to the cellulose. As this row of cells dries out,

each cell, in losing water, shortens its outer line. The pull so exerted causes the annulus to bend back very much as the arm of a half back bends back when he prepares to launch a forward pass. This opens the sporangial box, and the spores tend to stick to the outer end of the annulus. There are tremendous physical forces involved in this operation. The annulus has the elasticity of a watch spring and pulls hard to return to its original shape, but it is held open by the tensile strength of the water in it. Finally the equilibrium of forces is broken and the annulus snaps shut, throwing the spores violently into the air.

We have here a typical structural adaptation, since the effect is favorable to dispersal of the spores. They are thrown into the air usually, when the wind is blowing and usually after a rain, so that they have the best possible chance of being widely dispersed and of finding favorable conditions for germination. Furthermore, after the first cast the annulus cells fill up again at the next rain and make a second cast. So these sporangia continue opening and snapping shut whenever it rains and the wind again dries them out.

The point about this is that we are here dealing with cells which are dead long before they can function and which therefore under no conditions can fit the Lamarckian view. How well does the Darwinian theory fare in this case?

In the annulus we have a single row of cells, perhaps a dozen. Each has six walls. If the mechanism is to work three of the six walls must be lignified, but only three, and these must be the right ones. What are the chances, given random variation, of a cell wall being lignified at all? Rather slim in any event. But cell walls do become lignified at times and assuming that this may happen let us calculate the probabilities of the lignification taking place in those particular walls which would render the mechanism effective.

This brings me to the field of mathematics and if Mr. Cain were here tonight he would cheerfully testify that I am out of my depth. As well as I can make the calculation, the chances are one in six that one of the six walls will be lignified; one in six that five, one in sixteen that four, one in sixteen that three, and one in sixteen that two will be lignified. Then there is the chance that all six walls will carry lignin. Only one of these sixty-one possibilities is correct. According to my calculations, which are not guaranteed but which are substantially correct, the chances of all twelve cells in a row being lignified in exactly the right way would be one in 2,551,294,375,435,330,358,321.

The situation is still more complicated because the annulus represents



only twelve of the many cells constituting the wall of the sporangium. All other cells must remain unlignified while the annulus cells are being lignified in a definite pattern. The probabilities of this actually occurring stagger the imagination. It is no more likely than for us to imagine that every gaseous molecule in this room at the present time will happen by chance to move in one direction. We can be sure on practical as well as theoretical grounds that this is not going to happen. I maintain the impossibility of the annulus of a fern sporangium developing in the particularly effective form it shows by any imaginable random variation.

Any adequate theory of adaptation must cover all cases. Here is one definite instance which cannot be subject to explanation either on Lamarckian or Darwinian grounds. It is evident that explanations so far offered are inadequate to account for the facts. There is something else here which science has not yet succeeded in stating.

It may be that you expect me to offer a solution to this mystery. I can say, however, that I have not come here to instruct my old instructors but offer to their judgment the problem which I have stated. My function here is not so much to solve the riddle of the universe as to rejoice with you in the rounding out of half a century of honorable usefulness in the field of natural science and to wish the Elisha Mitchell Scientific Society and its members, my friends, many happy returns of the day.

## PROCEEDINGS OF THE THIRTY-THIRD ANNUAL MEETING OF THE NORTH CAROLINA ACADEMY OF SCIENCE

THE UNIVERSITY OF NORTH CAROLINA, CHAPEL HILL, N. C.,  
MAY 4 AND 5, 1934

The thirty-third annual meeting of the North Carolina Academy of Science was held at The University of North Carolina, May 4 and 5, 1934. The meeting was called to order at 9:30 a.m. on May 4, by the president, Dr. B. W. Wells. The reading of papers was begun promptly and continued until 12:30 p.m., when the following committees were appointed by the president:

Auditing: H. E. Fulcher, C. C. Hatley, J. G. Douglas.

Nominating: J. B. Bullitt, J. B. Derieux, Bert Cunningham.

Resolutions: P. M. Ginnings, W. E. Speas, D. B. Anderson.

The Academy then took a recess for luncheon.

The reading of papers was resumed at 2:15 p.m. and continued until 4:30 p.m., when the Academy went into business session.

The minutes of the previous meeting were approved as published in the *Journal of the Elisha Mitchell Scientific Society*.

Reports were then called for from the various committees.

The executive committee, consisting of B. W. Wells, the president of the Academy, Helen Barton, vice-president, H. L. Blomquist, secretary and treasurer, F. W. Sherwood, Charles M. Heck, E. T. Browne, reported as follows:

"The executive committee met in Raleigh on May 3 and again in Chapel Hill on May 5 with the following members present: B. W. Wells, H. L. Blomquist, F. W. Sherwood, Charles M. Heck, E. T. Browne. (Helen Barton was unable to attend due to illness.)

"The committee appointed E. T. Browne to preside at the meeting in place of Helen Barton, vice-president.

"The committee appointed F. W. Sherwood to act as temporary assistant to the secretary during the meeting.

"The committee acted favorably on the request of E. W. McChesney that the names after the title 'Blood Serum Proteins in Essential Epilepsy' on the program of the chemistry section be reversed."

The committee reported as elected to membership since the last annual meeting the following:

Boomhour, Elizabeth, Meredith College, Raleigh, N. C.  
Brandt, B. B., Zoology Dept., Duke University  
Butts, Helen E., Zoology Dept., Duke University  
Clevenger, C. B., State College, Raleigh, N. C.  
Cruse, Emmett E., Catawba College, Salisbury, N. C.  
Culbertson, James W., Zoology Dept., U. N. C.  
Frink, Horace Westlake, Psychology Dept., U. N. C.  
Fultz, Chester, Catawba College, Salisbury, N. C.  
Gayman, Marion, Catawba College, Salisbury, N. C.  
Hill, Douglas G., Chemistry Dept., Duke University  
Hofmann, J. B., State Forestry Dept., Raleigh, N. C.  
Hunt, Melba, Meredith College, Raleigh, N. C.  
McCay, M. S., Physics Dept., U. N. C.  
McNair, John C., Wilmington, N. C.  
Mouzon, J. C., Physics Dept., Duke University  
Olpin, A. R., Kendall Mills, Paw Creek, N. C.  
Oosting, H. J., Botany Dept., Duke University  
Perry, H. S., Botany Dept., Duke University  
Reddish, Paul S., Zoology Dept., Duke University  
Reid, W. A., State College, Raleigh, N. C.  
Sink, Woodford, Catawba College, Salisbury, N. C.  
Smith, F. F., Botany Dept., Duke University

"The committee ruled that the secretary be empowered to reinstate all persons who have forfeited the privileges of the Academy for non-payment of 1933 dues if these dues are paid before the end of the 1934 meeting.

Reinstated to membership:

Cameron, E. A., Mathematics Dept., U. N. C.  
Campbell, Roy J., Salem College, Winston-Salem, N. C.  
Nielsen, Walter, Physics Dept., Duke University  
Trentham, S. O., Mars Hill College, Mars Hill, N. C.

"The committee also reported the following losses during the year:

Lost by death:

Dr. James Munsie Bell, Dean of the School of Applied Sciences of the University of North Carolina,  
Dr. William Battle Cobb, Chairman of the Division of Soils of the North Carolina State College, and  
Dr. Francis Preston Venable, Professor Emeritus in the Department of Chemistry of the University of North Carolina.

Lost after removal from the state:

Alexander, A. E.  
Barkley, Mabel A.  
Brooks, F. P.

Cable, Louella E.  
Dendy, J. S.  
Githens, Sherwood, Jr.  
Tipton, S. R.  
Wager, Martha Cook.

Lost by resignation:  
Zener, Karl E.

Dropped from the roll for the non-payment of dues:  
Thirty-six former members.

"The committee accepted the invitation of the Woman's College of the University of North Carolina to hold its thirty-fourth meeting at Greensboro.

"The executive committee made the following recommendations to the Academy:

1. "That all bills presented in the Treasurer's Report be authorized and paid, and that the report be printed when audited.

2. "That Bert Cunningham be appointed a committee of one to select the books to be given to the winner of the High School Science Prize, and that he be authorized to draw upon the Treasury for as much as \$25.00 for the books; and that the Academy send a representative to the Richard J. Reynolds High School, Winston-Salem, to present the prize.

3. "That the Academy elect to life membership Dr. Collier Cobb, Professor Emeritus of Geology and former Chairman of the Department of Geology at The University of North Carolina. Dr. Cobb joined the Academy in 1902, and was its president in 1907, and has been an active member up to the present.

4. "That the secretary be instructed to strike from the mailing list of the *Journal of the Elisha Mitchell Scientific Society* the names of the members who have not paid their 1934 dues by the end of the meeting.

5. "That beginning with next year (1935), the payment from the Academy to the *Journal of the Elisha Mitchell Scientific Society* be changed from a flat rate of \$300.00 per year to \$1.00 per member in good standing.

6. "That a committee on school curriculum be appointed to coöperate with Mr. Allen, State Superintendent of Public Instruction."

The Academy considered the recommendations of the executive committee by sections and after some discussion, especially on section 5, all sections were adopted.

The Treasurer's report was as follows:

*Financial Statement, May 3, 1933-July 28, 1933*

		Expenditures	
Balance on hand, May 3, 1933..	\$516.56	Postage.....	\$1.00
Dues for 1933.....	80.00	Telegrams and telephoning...	.67
Initiation fees.....	14.00	Jour. of the E. M. S. S. bal.	
Interest on Savings.....	4.95	due.....	50.00
		Clerical assistance.....	8.10
Total.....	\$615.52	H. S. Essay Prize.....	25.00
Less expenditures (May 3-July		Sec.-Treas. com.....	9.40
28, 1933).....	98.56	Sec.-Treas. expenses to David-	
Balance.....	\$516.96	son meeting.....	4.29
		Tax.....	.10
Resources:		Total.....	\$98.56
Savings Account.....	\$501.85		
Check to H. L. Blomquist...	15.11		
	\$516.96		

The above report was made as of July 28, 1933.  
Submitted by H. R. Totten, (Old) Secretary-Treasurer.

*Financial Statement, July 28, 1933, to May 3, 1934*

		Expenditures	
Balance on hand, July 28, 1933.	\$516.96	Stationery, printing and post-	
Dues for		age.....	\$44.84
1933.....	62.00	Same.....	40.67
1934.....	192.00	Postage on H. S. Essays.....	3.06
Initiation fees, 1934.....	24.00	Addressographing.....	14.95
Interest on savings.....	10.07	Railway Express.....	.50
Allotment from A. A. A. S....	42.50	Telegrams and telephoning...	1.07
Refund on overpay.....	.40	Clerical Assistance.....	47.00
		Dues refund to Sec.....	2.00
Total.....	\$847.93	Sec.-Treas. Commiss.....	28.20
		Journal of the E. M. S. S. (par-	
		tial payment).....	150.00
		Tax on checks.....	.18
		Total.....	\$332.47
		To balance.....	515.06
			\$847.53
		Outstanding obligations: Bal-	
		ance due the Journal of the	
		E. M. S. S.....	150.00

	1933	1934
Savings account.....	\$496.89	\$511.92
Checking account.....	13.67	3.54
Cash on hand.....	6.00	.40
	\$516.56	\$515.86
Outstanding obligations.....	50.00	150.00
	\$466.56	\$365.86
To balance (net loss).....	64.05	100.70
	\$530.61	\$466.56

The above report was made as of May 3, 1934.

Submitted by H. L. Blomquist, Secretary-Treasurer.

Audited by H. E. Fulcher,

C. C. Hatley,

J. G. Douglas.

Date: May 4, 1934.

The auditing committee reported that they had examined the accounts of the treasurer for the periods of May 3, 1933-July 28, 1933; and of July 28, 1933-May 3, 1934, and found them correct.

The reports of the treasurer and the auditing committee were accepted.

The committee on high school science, consisting of Bert Cunningham, Chairman, H. B. Arbuckle, Lena Bullard, C. M. Heck, C. E. Preston, and R. N. Wilson, reported as follows:

"The committee's activities of chief concern had been (1) the supervision of the high school science essay contest; and (2) a new matter referred to it for consideration by the president of the Academy.

"The committee elected the following judges for the essay prize: Douglas G. Hill, G. H. Satterfield, W. E. Speas, who announced the following decision:

Number of contestants: 32.

Winner: Miles C. Horton of Richard J. Reynolds High School, Winston-Salem.

Title: The Romance of Radium.

"The committee recommends that the secretary select a member of the Academy to present the award, and that the necessary expenditures be authorized.

"The committee recommends that the awarding of the prize be con-

tinued, and that the field for 1935 be biology (zoology, botany, physiology) and physical geography.

"The committee recommends that a special committee be appointed to cooperate with the State Department of Education in the reorganization of the curriculum."

The report of the committee on high school science was accepted and its recommendations were adopted.

The committee on standardization of college science courses, consisting of Bert Cunningham, Chairman, P. M. Ginnings, H. R. Totten, J. B. Bullitt, and Karl H. Fussler, made the following report:

"Section A. The committee has studied the matter of standardization and profited by the findings of various sub-committees appointed by Dr. Hillman. On the basis of this study the committee has come to the following conclusions:

1. "It is inadvisable to attempt standardization of the content, sequence, or equipment for chemistry and biological sciences.

2. "That the elementary sciences should be given on a standardized basis of eight semester hours credit.

3. "That emphasis should be placed on adequate equipment and materials for courses offered in standard or junior colleges.

4. "That serious consideration be given to the problem of the teacher's training and his teaching load; that full teaching credit, hour for hour should prevail, except where assistants are wholly responsible for laboratory work; and that a teaching load should not exceed 15-16 hours per week."

"Section B. Although doubting the advisability of standardization, the committee believes a fundamental problem is involved and recommends an alternative procedure:

1. "That the Academy establish an appraisal committee which shall have as its function the evaluation of the work in sciences in the various institutions.

2. "That the members of this committee be elected by the Academy, three from physics, three from chemistry, and three from biology.

3. "That this committee shall, upon request from proper officials of any institution, investigate through a sub-committee and make suggestions as to improvements.

4. "That the favorable findings of the committee shall be reported to the Academy and the Academy's records will constitute the accredited list, indicating those institutions whose courses meet the approval of the Academy."

This report was taken up by sections. After a short discussion, Section A was approved. Section B provoked considerable discussion pro and con and was finally tabled. The committee was continued.

The legislative committee, made up of Z. P. Metcalf, Chairman, W. L. Poteat, and C. S. Brimley, did not have any report to make at this time.

Special committees honoring the memories of three members reported as follows:

DR. FRANCIS PRESTON VENABLE

In the passing from this life March 17, 1934, of Francis Preston Venable, the North Carolina Academy of Science recognizes the loss of a member of unusual distinction. The whole of his mature life was devoted to the betterment of educational facilities in the southern states. He was a great and inspiring teacher, both in the lecture room and in the laboratory. A long list of published investigations are a monument to his skill and patience, of which his work on the compounds of zirconium is classical. A number of texts make clear and understandable to any earnest student, special fields of investigation which had remained obscure to all but few specialists. But his interests were far broader than those of chemistry and he was ever at the command of any worker, the neophyte or the master, in any field of scientific endeavor, who claimed assistance from his wide learning and broad culture. His was a life of dignity, distinction, and very great usefulness.

He was born in Prince Edward County, Virginia, November 17, 1856. After a childhood in South Carolina, he went with his family to Charlottesville, Virginia, where his father, a distinguished mathematician, was a member of the faculty. Venable's tastes lay in another direction, and under the tutelage of Mallet, he acquired a laboratory technique which determined his career as an experimentalist in chemical problems. Leaving the University of Virginia in 1879, after a year in Bonn, he received a Ph.D. at Göttingen in 1881. Eight years later he spent a year of study at Berlin. Meanwhile he had come to Chapel Hill in 1880, and with very sketchy equipment and resources, began the organization of a department of chemistry which now has eight professors, and a fine equipment housed in a modern laboratory, Venable Hall, named in his honor. In 1900, regretfully, for it seemed to be the end of his career as a scientist, he responded to the call of duty and assumed the presidency of the University, a load he carried for fourteen fruitful years. His health badly jeopardized, he retired for a short period of recuperation, but soon returned to assume the duties of a professor in



the department of chemistry. In 1930, after a half century of service, he was made professor *emeritus*, gradually gave up active work, and lived in complete retirement the last year or two.

Venable was vice-president of the American Association in 1899 and president of the American Chemical Society in 1905. He was a member of the Philosophical Society, the London Chemical Society, the Elisha Mitchell Scientific Society, the North Carolina Academy of Science, the Advisory Committee of the Chemical Warfare Service, and many other organizations in whose work he took an active part. He was made an honorary Doctor of Science by Lafayette and the degree LL.D. was conferred on him by Jefferson Medical College and the Universities of Pennsylvania, South Carolina, and Alabama.

To his family, the North Carolina Academy of Science extends its deep sympathy, and makes this acknowledgment of its own great bereavement. It directs that this statement be spread upon its minutes and that the Secretary transmit a copy to the bereaved family.

F. K. CAMERON,  
A. S. WHEELER,  
W. C. COKER,  
*Committee.*

#### DR. JAMES MUNSIE BELL

The death of James Munsie Bell on March 3, 1934, brings a heavy loss to this Academy. For many years he has been one of its most active and devoted members, contributing largely and generously to its success, especially in its Chemical Section. He served as Vice-President in 1921 and as President in 1928.

Dr. Bell was born at Chesley, Ontario, Canada, in 1880. He graduated with the degree of A. B. at the University of Toronto, in 1902, and later received his A. M. from the same institution. As Sage Fellow at Cornell University he received his Ph.D. in 1905. During the next five years, as research chemist with the U. S. Department of Agriculture, he published various papers upon soils and fertilizers. He entered the faculty of the University of North Carolina in 1910, became head of the Department of Chemistry in 1921 and Dean of the School of Applied Science in 1929. His industry, his conscientious devotion to duty, and his sane counsel have made him an invaluable member of the University's Advisory Committee and of its various administrative boards. As a member of the leading chemical societies and of the N. C. Academy of Science and as Permanent Secretary of The Elisha Mitchell Society,



JAMES MUNSIE BELL  
1880-1934



he exerted wide influence in scientific circles. He was more than a scientist. He played a large part in all civic and social activities of his community. His interest, his kindness, his ability, and his wisdom will be missed on every hand.

This Academy and this state have lost a scholar and administrator of unusual attainments, and we who had the privilege of knowing him have lost a friend whose place can never be filled. No resolution that we may offer can adequately express our affection for him nor our present distress, but as an inadequate testimony we spread this memorial on our minutes and send a copy to his widow (Mrs. Mary B. Bell, Chapel Hill, N. C.) and to his mother (Mrs. Hannah M. Bell, Toronto, Canada).

JAMES B. BULLITT,  
JAMES TALMADGE DOBBINS,  
OTTO STUHLMAN, JR.,  
*Committee*

DR. WILLIAM BATTLE COBB

On November 22nd of last year the Academy suffered a loss by the untimely death of Dr. William Battle Cobb, head of the Department of Soils at North Carolina State College.

Dr. Cobb was born at Cambridge, Mass., on November 23, 1891, but spent his boyhood in Chapel Hill. He received his A.B. degree from the University of North Carolina in 1912 and his A.M. degree in 1913. From 1911 to 1913 he was assistant in Botany at the University.

For five years thereafter he was engaged in soil survey work with the United States Department of Agriculture. During the war he entered the army air service where he received a commission of lieutenant. Later he resumed soil survey work and in 1920 he introduced the use of the airplane in making a soil survey of the inaccessible areas of Tyrrell County, North Carolina.

Prior to his appointment as head of the Soils Department at North Carolina State College in 1924, he served as soils specialist of the American Rural Planning Association of Wisconsin and as Associate Professor of Agronomy in charge of Soils at Louisiana State University.

During his nine years in his last position Dr. Cobb served on the American Organizing Committee of the First International Congress of Soil Science. In 1932 he was President of the American Soil Survey Association. Two summers were spent teaching Soils and Geology at the University of North Carolina and three summers were devoted to further soil survey work in North Carolina and in middle western states.

Dr. Cobb received his Ph.D. degree in Geology from the University of North Carolina in 1927.

In addition to the formal honors accorded him in recognition of his work, Dr. Cobb was considered one of the foremost authorities in the United States in matters pertaining to soil classification.

He is survived by his wife, whom he married in 1920, and three children.

It is characteristic of his devotion to his work that he presented his last paper at a meeting of the American Soil Survey Association while suffering from an illness that proved fatal a few days later.

Dr. Cobb built a living memorial in the stimulus he has contributed to a high caliber of professional work in soils and in the invaluable help he has given to his associates in teaching and research.

Be it resolved that this note of appreciation of the services of Dr. Cobb be published in the Proceedings of the North Carolina Academy of Science and that a copy be sent to members of his family.

L. G. WILLIS,  
I. V. SHUNK,  
C. B. WILLIAMS,  
*Committee.*

The reports were accepted by a standing vote, and the secretary was instructed to place the reports in the minutes and to send copies to the respective families.

The general resolutions committee reported as follows:

- I. *Whereas* the North Carolina Academy of Science is being entertained by the University of North Carolina,  
*Be it resolved* that appreciation and thanks be extended to the host.
- II. *Whereas* the Vice-president of our Academy, Miss Helen Barton, is unable to attend our meeting on account of illness,  
*Be it resolved* that a note of regret and sympathy be transmitted from the Academy to Miss Barton.
- III. *Whereas* Dr. E. E. Randolph is unable to attend the meeting of the Academy due to the sudden death of his mother,  
*Be it resolved* that a note of sympathy be transmitted from the Academy to Dr. Randolph.

P. M. GINNINGS,  
*Chairman.*

The above resolutions were adopted.



WILLIAM BATILE COBB  
1891-1933



The nominating committee submitted the following nominations:

*President*—H. R. Totten, The University of North Carolina;

*Vice-president*—P. M. Ginnings, Woman's College;

*New member of the Executive Committee* (for three years)—W. E. Speas, Wake Forest College.

The nominations were accepted and the secretary was instructed to cast the ballot of the Academy for the nominees.

The president appointed to the committee on public school curriculum for the following year: C. E. Preston, Thelma Howell, Lena Bullard, and Bert Cunningham.

The president appointed to the high school science committee for the following year: Bert Cunningham (Chairman), Duke University, H. B. Arbuckle, Lena Bullard, C. M. Heck, C. E. Preston, and R. N. Wilson.

The business meeting then adjourned.

At 7:00 p.m. the members of the Academy were entertained at a complimentary dinner given by The University.

The Academy reconvened at 8:30 p.m. with E. T. Browne presiding in the absence of Vice-president Helen Barton. J. W. Lasley, Jr., President of the Elisha Mitchell Scientific Society, welcomed the Academy to The University of North Carolina. E. T. Browne presented President B. W. Wells who delivered his presidential address on the subject, "Galls and 'galls'," illustrated with lantern slides.

The Academy met in sections on Saturday morning with President Wells presiding over the general section; E. K. Plyler over the physics section, with C. N. Warfield as secretary; E. L. Mackie over the mathematics section, with E. R. C. Miles as secretary; and H. D. Crockford over the chemistry section, with R. W. Bost as secretary.

The following officers were elected by the respective sections:

*North Carolina Section of the American Chemical Society*—Chairman, J. H. Saylor, Duke University; Vice-chairman, R. W. Bost, The University of North Carolina; Secretary-treasurer, W. C. Vosburgh, Duke University; Councilor, Robert N. Isbell, Wake Forest College; Executive committee: the officers, F. W. Sherwood, North Carolina Experiment Station, and H. D. Crockford, The University of North Carolina.

*Mathematics Section*—Chairman, E. R. C. Miles, Duke University; Secretary, W. N. Mebane, Jr., Davidson College.

*Physics Sections*—Chairman, Calvin N. Warfield, Woman's College of The University of North Carolina; Secretary, J. S. Meares, North Carolina State College.

The following papers were presented. Those marked with \* appear



in full in this issue. Those marked x are abstracted in this issue. For those not marked, no abstract has been received. Those marked † were read by title.

## GENERAL SECTION

x*Axial Duplication in Serpents* (Lantern). BERT CUNNINGHAM, Duke.

†*Growth of Chemical Industries in North Carolina and in Adjoining States.*

E. E. RANDOLPH, State.

†*History of Downy Mildew of Tobacco.* F. A. WOLF, Duke.

x*Effects of Variation in Length of Day on the Growth and Dormancy of Tree Seedlings* (Lantern). PAUL KRAMER, Duke.

x*Fertilizer and Soil Reaction of Strawberry Soils* (Lantern). R. A. LINEBERRY, U. S. D. A.

*Sex-Determination in the Wasp Habrobracon* (Lantern). C. H. BOSTIAN, State.

*The Homopterous Head* (Lantern). Z. P. METCALF, State.

*Parasitic Flowering Plants of North Carolina* (Lantern). W. C. COKER, U. N. C.

*Rhythm, Synchronism and Alternation in the Stridulation of Orthoptera* (Lantern). B. B. FULTON, State.

x*Seasonal Distribution of Lake Raleigh Plankton* (Lantern). L. A. WHITFORD, State.

x*The Nutrition of Flabellula mira* Schaeffer. NOLAN E. RICE, Duke.

x*The Effect of Certain Salts of Sea Water Upon Reproduction in the Marine Amoeba, Flabellula mira* Schaeffer (Opaque Lantern). HELEN BUTTS, Duke.

\**Anatomy of the Transition Region of Helianthus annuus* (Lantern). ALBERT F. THIEL, W. C. of U. N. C.

*The Science and Mathematics Requirements for the Liberal Arts Degree in Southern Colleges and Universities.* P. M. GINNINGS, Greensboro College.

*Animal Succession in a Forest Series.* ELOISE E. GREENE, Queen's-Chicora College.

x*Relative Humidity or Vapor Pressure Deficit?* (Lantern). DONALD B. ANDERSON, State.

*Shall We Encourage Undergraduate Research? If so, How?* CHAS. M. HECK, State.

x*North Carolina Talc Deposits.* J. L. STUCKEY, State.

x*Comparison of Some Presumptive Tests for the Coli-Aerogenes Group of Bacteria.* I. V. SHUNK, State.

- x*Effect of Tread Upon the Skidding of Automobile Tires.* J. B. DERIEUX, State.
- The Significance of the Oxidation-Reduction Potentials of a Soil.* L. G. WILLIS, State.
- x*Soil Contamination as a Factor in Crop Infestation of Common Tobacco Mosaic* (Lantern). S. G. LEHMAN, State.
- x*Studies of the Influence of Vegetation Cover upon Stormflow and Erosion* (Lantern). C. R. HURSH, Appa. For. Exp. Sta.
- x*Syncytial Structures Produced by Lymphocytes of Sea Urchins* (Lantern). IRENE BOLIEK, U. N. C.
- x*Economic Possibilities of Pulping Timber Growth of Lowlands of the Coastal Plain.* E. E. RANDOLPH and W. L. BELVIN, State.
- The Calcium and Phosphorus Content of the Blood Serum of Normal and Insane Male Persons.* G. HOWARD SATTERFIELD and W. S. McKIMMON, State.
- Polyporus curtisii the Cause of Heart Rot of Peach* (Lantern). R. F. POOLE, State.
- x*"Meteor Craters" of the Carolinas* (Opaque Lantern). WM. F. PROUTY, U. N. C.
- Some Fungi Which Prey on Animals* (Lantern). JOHN N. COUCH, U. N. C.
- x*The Effect of Fertilization Upon Nitrogen Content of a Cecil Clay Loam Soil Over a Period of 31 Years* (Charts). G. M. GARREN, State.
- x*Cell Behavior in the Metamorphosis of the Halichondrine Sponge Larva* (Blackboard). H. V. WILSON, U. N. C.
- x*What Lies Under the Coastal Plain?* (Opaque Lantern). G. R. MAC-CARTHY, U. N. C.
- The Genus Cuscuta, "Dodders," in North Carolina.* BUDD ELMON SMITH, U. N. C.
- †*Some Recent Contributions to Our Knowledge of Atomic Structure.* C. W. EDWARDS, Duke.
- The Respiratory Function in the Avian and Mammalian Embryo* (Lantern). F. G. HALL, Duke.
- x*Some Teratological Early Embryos of the Frog* (Lantern). JAMES W. CULBERTSON, U. N. C.
- x*Some Notes on the Silurian System of Eastern Tennessee.* W. F. PROUTY and J. G. DOUGLAS, U. N. C.
- †*Bivalve Opening Power of Starfish* (Lantern). HERBERT F. PRYTHERCH, Beaufort.
- Some Ferns Rare to North Carolina* (Lantern). H. L. BLUMQUIST, Duke.

- xThe Frogs and Toads of Beaufort County* (Lantern). B. B. BRANDT, Duke.
- xThe Parasites of the Horned Passalus*. A. S. PEARSE, Duke.
- xFossil Whales of the North Carolina Miocene* (Opaque Lantern). WM. F. PROUTY, U. N. C.
- Apparatus for Studying the Development of Hen Eggs Under Increased Atmospheric Pressure* (Lantern). BERT CUNNINGHAM, Duke.

## MATHEMATICS SECTION

- A Generalization of Harmonic Functionals*. F. G. DRESSEL, Duke.
- Some General Types of Symmetric Green's Functions*. W. W. ELLIOTT, Duke.
- xConics of the Fourth Order Contact*. J. S. LASLEY, JR., U. N. C.
- A Symbolic Method in the Calculus of Extensive Quantities*. J. M. THOMAS, Duke.
- xEquations of Certain Osculants to Plane Curves*. E. A. CAMERON, U. N. C.
- Note on Stieltjes Integrals Containing a Parameter*. E. R. C. MILES, Duke.
- Some Properties of the Cauchy Product Applied to Double Series*. JULIA DALE, Duke.

## PHYSICS SECTION

- xThe Coefficient of Friction of Rubber*. J. B. DERIEUX, State.
- xA Preliminary Study of Temperature, Time and Strain Relationships for Rubber*. MILTON L. BRAUN, Catawba.
- xIntensity of the Electrodeless Hydrogen Spectrum as Conditioned by Pressure and Discharge Tube Dimensions* (Lantern). M. S. McCAY, U. N. C.
- Intensity of the Hydrogen Spectrum as Determined by the Frequency of the Electric Field in Electrodeless Discharge* (Lantern). OTTO STUHLMAN, JR. and M. S. McCAY, U. N. C.
- Selective Radio Frequency Absorption in Iodine Vapor* (Lantern). W. L. SMITH and OTTO STUHLMAN, JR., U. N. C.
- The Infrared Absorption of Acid Solutions*. E. S. BARR and E. K. PLYLER, U. N. C.
- The Infrared Absorption of Water as a Function of Thickness*. C. J. CRAVEN and E. K. PLYLER, U. N. C.
- The Infrared Absorption of Hydroxides and Hydrolizing Salts in Aqueous Solutions*. WALTER GORDY and E. K. PLYLER, U. N. C.

*The Infrared Absorption of Alcoholic Solutions.* F. D. WILLIAMS and E. K. PLYLER, U. N. C.

*The Effect of Nitrogen on the Mercury Afterglow.* M. M. MANN and WALTER M. NIELSEN, Duke.

*The Raman Effect in Carbon Dioxide at Different Temperatures.* ISABEL HANSON and C. C. HATLEY, Duke.

*Development of a Source of Doubly Charged Magnesium Ions.* N. H. SMITH and J. C. MOUZON, Duke.

*The Absorption of Secondary Cosmic Radiation in Lead.* KARL MORGAN and WALTER M. NIELSEN, Duke.

#### EXHIBITS

*Tubes of Different Media Used in Presumptive Tests for the Coli-Aerogenes Group.* I. V. SHUNK, State.

*Models of the Homopterous Head.* Z. P. METCALF, State.

*An Example of Double Cutinization—A Microscopic Mount of the Outer Epidermal Wall of Clivia.* DONALD B. ANDERSON, State.

*Commercial Exhibits.* PHIPPS and BIRD, Richmond, Virginia.

*Wild Flower Show (by Class in Botany 43).* H. R. TOTTEN, U. N. C.

*Exhibits of Whale Remains and of Maps Showing Craters.* WM. F. PROUTY, U. N. C.

#### NORTH CAROLINA SECTION OF THE AMERICAN CHEMICAL SOCIETY

*The Chlorination of 2-Nitro-p-Cymene.* A. S. WHEELER and J. M. EARLY, U. N. C.

*The Dipole Moments of Some Mono-Substituted Mesitylenes.* PAUL GROSS, FRANCES BROWN, J. M. A. DEBRUYNE, Duke.

*The Preparation of Perrhenic Acid.* J. T. DOBBINS and J. K. COLE-HOUR, U. N. C.

*The Alkalinity of Organic Nitrogenous Fertilizers.* L. G. WILLIS, State.  
*2,4-Dinitrochlorobenzene as a Reagent in Qualitative Organic Analysis.*  
R. W. BOST, J. O. TURNER, R. E. GEE and FRANK NICHOLSON, U. N. C.

*The Distribution of Hydrogen Halides between Water and Some Organic Solvents.* J. H. SAYLOR, WILLIS J. SULLIVAN, MARY NEW, and C. B. GALLOWAY, Duke.

*The Catalytic Decomposition of Ethanol Over Certain Native Minerals.* R. K. NEWTON and NEVILLE ISBELL, Wake Forest.

*The Ionization Constants of Certain Sulfur Derivatives of Acetic Acid.* H. D. CROCKFORD and T. B. DOUGLAS, U. N. C.

*Darkfield Investigation of Fibers* (Lantern). H. T. CLIFFORD and F. K. CAMERON, U. N. C.

*Blood Serum Proteins in Essential Epilepsy*. B. W. MACKENZIE and E. W. MCCESNEY, U. N. C.

The following abstracts have been received:

*Axial Bifurcation in Reptiles*. BERT CUNNINGHAM.

Axial bifurcation in reptiles was apparently first described by Aristotle who notes the occurrence of two heads attached to a single serpent body. Except for Pliny and Aelianus further notation seems to be absent until the middle ages when several authors describe specimens and, with the advent of illustration in printing, figure them. Probably the oldest figure of a two-headed serpent is the one presented by Licetus (1643). It is possible that Porta may have an earlier figure, and Cube (1536) published a figure of a three-headed serpent, the authenticity of which may be doubted. The figure by Cube shows the reptile disporting in the water, while the only record upon which the figure might be based stated that the specimen was taken in the Pyrenees Mountains.

From time to time various authors have attempted to collect in a single paper all the recorded occurrences of serpents showing duplication of any parts of the axial skeleton. Several of these papers are worthy of note. Of the more recent summaries, Johnson's (1901) paper stands out since he secured as many specimens as available and studied them with the x-ray. He described and figured some twenty-five specimens, eight of which had not been previously described. He also cited numerous cases reported by earlier authors, which in the very nature of things he was unable to study. An excellent bibliography accompanied the paper.

In 1921 Cantoni published a paper in which he describes some new specimens; but the real value of his paper lies in the fact that he summarised the previous reports. Strangely enough his paper duplicates Johnson's report but little; and the two papers taken with Strohl's paper which was published later, together with their bibliographies form an excellent foundation for the student of axial duplication in serpents.

In 1925 Strohl printed a rather elaborate paper in which he summarised all the cases known to him, a total of 68 in all. This article also carries an excellent bibliography and taken with Johnson and Cantoni includes most but not all of the specimens reported before 1925. Strohl adds two specimens of his own, one of which is exceedingly inter-

esting since there is but a single head, which duplicates only at the base of the skull, and there are two perfectly good vertebral columns arising from the duplicate bases. Amaral (1926) examined the specimens in various museums, and added more new descriptions than any other worker, his list including some nine new specimens.

In a recent article Heasman (1933) fully described a specimen and notes in his introduction that this individual brings the total of known specimens up to eighty.

That this number is considerably short of the total is quite evident. There have been more than 75 figures (including Heasman's specimen) printed of different snakes having varying degrees of axial duplicity. To this may be added an almost equal number of other specimens which have been described but not figured, bringing the "known cases" up to approximately 150.

The degree to which duplication has been accomplished in the various animals is extremely variable. Three rather distinct types, however, might be considered, namely: (1) duplication of head parts only, body and tail single, (2) duplication of head parts, and part of body, tail single, (3) duplication of tail and part of body, head single. Of these three types the second is far more common and the last most rare. There is a single specimen, described by Wyman (1862), which does not fit into any of the above categories since the head and "neck" are double, followed by a single vertebral column which becomes duplicate in the middle of the body, then single further caudad and finally double again in the tail region.

Long ago Mitchell disposed of the idea that monsters of this type were confined to a genus of their own, and a resurvey of the reported cases, in which the classification was indicated, shows them to be distributed in at least twenty genera and about forty species. This of course is probably considerably below the actual number of genera and species involved. Thus far there is no satisfactory evidence that the monsters occur more often in one genus than another if the relative abundance of a given genus is considered. Efforts to determine the relative occurrence in oviparous species as compared to ovoviviparous species have not yielded any information of importance, this type of monster occurring in either kind of animal with relative frequency.

Neither is there any good evidence that the duplicity is more likely to occur on one continent than another. To be sure the northern hemisphere furnishes more than three-fourths of these specimens, the source of which may be determined, and this three-fourths is fairly well divided

between the United States and Europe. But this does not necessarily mean that the occurrence is more frequent in the temperate zone—it may simply mean there are more observers, or that such monsters have better chances of getting into print in these regions.

The cause or causes of axial duplicity in serpents are not evident, and although numerous explanations have been offered, none of them alone seems to apply to all cases. Differential growth rates due to environmental factors, regeneration, two embryos within a single egg, or two embryonic disks on a single ovum; none of these alone seems to meet the requirements of all cases.

In the face of the present facts it does not seem less reasonable to suppose that different causal factors are involved in different cases, than to accept Heasman's proposal that, "a common cause is to be accepted until proved otherwise."

*Effects of Variation in Length of Day on the Growth and Dormancy of Tree Seedlings.* PAUL J. KRAMER.

All species of tree seedlings investigated showed definite responses to variations in length of day. Red gum and post oak subjected to an eight and one-half hour day grew much less than with the normal length of day. Trees of these species given electric light from sunset until midnight made more growth than did the trees receiving normal length of day. Red gum seedlings given electric light all night made even more growth than those given electric light until midnight. Both red gum and post oak seedlings became dormant much sooner under normal day conditions than when given additional electric light.

Yellow poplar seedlings given a short day became dormant sooner than those exposed to a normal length of day. Trees given electric light until midnight never became dormant, but continued to produce new leaves all winter. Seedlings of yellow poplar, red gum, and red oak were brought indoors early in January and subjected to long and short day conditions. In all cases the long day trees came into leaf sooner than those receiving short day treatment.

The results of these experiments indicate that both the rate of growth and length of the dormant period of the seedlings of certain species of trees may be affected by the length of day or photoperiod to which they are exposed. It seems probable that mature trees of these species are affected in the same manner. It is also probable that many other species of trees react to variations in the photoperiod and that it is one of the principal factors controlling both the onset and the breaking of dormancy.

*Fertilizer and Soil Reaction of Strawberry Soils.* R. A. LINEBERRY.

Results of fertilizer experiments on the strawberry soils of eastern North Carolina show most vigorous plants, better plant viability, largest yields, and better strawberries from the use of a fertilizer containing 5 per cent nitrogen, 8 per cent phosphoric acid, and 6 per cent potash, when applied semi-annually at the rate of 750 pounds per acre in August and November. Fertilizers with decreased and increased percentages of nitrogen or decreased and increased percentages of potash did not give as favorable results.

Potash increased the carrying and keeping qualities of the strawberries. A fertilizer containing 6 per cent potash gave the best results.

The viability of strawberry plants was found to be correlated, in a general way, with the reaction of the soils. Fields where strawberry plants died were found more acid than nearby fields with vigorous plants. When soil was made acid by the addition of sulphur, the viability of plants decreased as the pH of the soil was lowered. On soils made neutral by the addition of lime, the viability of strawberry plants increased as the soil approached neutrality up to a pH of about 6.0. The periodic addition of small quantities of lime and the use of physiologically alkaline fertilizers may be a means of preventing loss of strawberry plants on these soils.

The viability of strawberry plants was low where the soil's pH was 4.5 or lower. The work as a whole indicates the optimum pH for strawberries on the sandy loam soils of the Chadbourn, North Carolina, section to be about 6.0.

*Seasonal Distribution of Lake Raleigh Plankton.* L. A. WHITFORD.

Bi-weekly counts of the plankton of Lake Raleigh during the year ending May 15, 1934, show that with the exception of *Anabaena* no organism reached great enough abundance to have caused taste or odor in the city water. On Aug. 10 over 1000 colonies of *Anabaena catenula* per c.c. were present and gave a decided moldy hay odor to the water. No odor was reported in city tapwater, however.

The following genera were next in abundance: *Staurostrum* (560 June 15), *Synedra* (470 March 15), *Cosmarium* (380 November 15), *Scenedesmus* (45 August 20), and *Trachelomonas* (25 December 15). There seemed to be no correlation between the abundance of any organism and ordinary weather conditions.

*The Nutrition of Flabellula mira Schaeffer.* NOLAN E. RICE.

*Flabellula mira* Schaeffer, a marine amoeba, has been cultured on 1.5



per cent artificial sea-water-wheat-extract-agar plates for more than a year. The amoeba was characterized by an anterior rim containing refractile bodies. "Giant" amoebae were observed rather frequently. No relationship between "giants" and dilute solutions of lactic acid was observed. All of the animals left microscopic trails or paths on agar surfaces. The paths were probably a result of the weight of amoebae or a shearing off of the prominences on agar surfaces. *Flabellula mira* has been cultured successfully for five months on pure strains of the bacteria, *Pseudomonas striata*, *Flavobacterium denitrificans*, and *Achromobacter* sp., and a mixture of *Achromobacter* sp. and *Serratia rubropertincta*. Pure strains of the same bacteria served as adequate diets for *F. mira* if 1 per cent sucrose, dextrose, lactose, maltose, or soluble starch, 0.2 per cent leucine, glycine, alanine, or tyrosine, or various mixtures of these carbohydrates and amino acids were used as substrates for the bacteria. *Flabellula mira* was unable to utilize any of these substances or mixtures for continuous growth and reproduction; living bacteria alone sufficed for an adequate diet, for *F. mira* ceased to grow and reproduce when given dead bacteria of the same species. It was demonstrated that *F. mira* obtained all essential food substances from living bacteria which were either in a growing, reproducing condition or in a dormant (resting) state. Nutrients dissolved in the medium were unnecessary in the diet. Evidence shows that *F. mira* was insensitive to the presence of food, i.e. bacteria, which have served as an adequate diet.

*The Effect of Certain Salts of Sea Water upon Reproduction in the Marine Amoeba, Flabellula mira* Schaeffer. HELEN E. BUTTS.

*Flabellula mira* was cultured in flasks for one week at 30°C. in artificial sea water and various combinations of salts. The number of amoebae inoculated and the final number in the cultures were calculated from ten samples from each culture under the microscope with a Levy counting chamber.

*Flabellula mira* is able to reproduce in concentrations of artificial sea water from 20 per cent to at least 150 per cent. Reproduction below 20 per cent is rare and no reproduction occurs in distilled water. Reproduction in a mixture of  $\text{CaCl}_2 + \text{MgCl}_2 + \text{KCl} + \text{NaCl}$ , of  $\text{CaCl}_2 + \text{MgCl}_2 + \text{NaCl}$ , and of  $\text{CaCl}_2 + \text{KCl} + \text{NaCl}$ , each salt in the proportion one to another in which they exist in artificial sea water, is nearly comparable to that in artificial sea water.

No reproduction occurs in isotonic solutions of single salts nor in the following mixtures:  $\text{CaCl}_2 + \text{KCl}$ ,  $\text{MgCl}_2 + \text{KCl}$ ,  $\text{MgCl}_2 + \text{KCl} +$

$\text{NaCl}$ ,  $\text{CaCl}_2 + \text{MgCl}_2 + \text{KCl}$ . Some reproduction occurs in mixtures of  $\text{CaCl}_2 + \text{NaCl}$  and  $\text{MgCl}_2 + \text{NaCl}$ .

There is an indication of a correlation between the optimum dilution or osmotic concentration and the monovalent divalent cation ratio. Within the ranges of pH values in the experiments the hydrogen-ion concentration of the solutions does not affect the results of three experiments.

*Relative Humidity or Vapor Pressure Deficit?* DONALD B. ANDERSON.

The absolute amount of water in the atmosphere has little, if any, direct effect upon plant or animal life. The relation between the actual water content of the atmosphere and the capacity of the atmosphere at the saturation point is significant. This relation may be expressed either as relative humidity and measured in percentage of saturation or as vapor pressure deficit and measured in millimeters of mercury. The latter method is to be preferred in biological work for the following reasons:

1. The vapor pressure deficit varies more widely during temperature changes than does the relative humidity and is therefore a more sensitive indicator of the moisture conditions of the atmosphere.

2. Areas having equal relative humidities do not have comparable atmospheric moisture conditions unless temperatures are identical. Atmospheric moisture conditions as they influence the rate of evaporation are comparable in different areas that have the same vapor pressure deficits.

3. The relative humidity alone gives no indication of the atmospheric moisture conditions influencing evaporation. Areas with high relative humidities may be very dry or very wet. The vapor pressure deficit does indicate the atmospheric moisture conditions influencing evaporation.

*North Carolina Talc Deposits.* J. L. STUCKEY.

Talc deposits associated with marble have been known and worked for many years in Macon and Cherokee counties, North Carolina. This marble, known as the Murphy Marble outcrops as a narrow band from Hewitts on the Nantahala River along the Valley and Notley Rivers to the Georgia line. More than twenty-five deposits of talc have been reported in this area. The talc occurs as lenses and sheet-like bodies in the marble. The lenses are often barely twice as long as they are broad and thick while the sheets are often thin and drawn out. The talc

appears to pass into the marble with very thin edges. The chief impurities in the talc are silicate minerals rich in magnesia. These minerals together with the talc have been described as having been derived from the magnesium carbonate in the sedimentary limestone. Recent microscopic study of the talc and associated minerals indicate that the marble has been partially silicified and replaced by talc and tremolite. In some of the deposits talc has directly replaced quartz or marble, in other deposits tremolite has replaced quartz or marble and in turn has been replaced by talc. Indications are that the talc has been formed by hot solutions and not by simple metamorphism of the magnesium carbonate in the limestone. The hot solutions were probably furnished by quartz diorite dikes which are abundant in the region and later than the metamorphism of the sediments.

*Comparison of Some Presumptive Tests for the Coli-Aerogenes Group of Bacteria.* IVAN V. SHUNK.

A comparative study has been made of four presumptive test media for detection of members of the coli-aerogenes group of bacteria in water: plain lactose broth and brilliant green lactose peptone bile as recommended by Standard Methods of Water Analysis for 1933, crystal violet broth as recommended by Salle (Journ. Bact. 20: 388, 1930) and basic fuchsin broth as recommended by Ritter (Jour. Amer. Water Works Assn. 24: 413, 1932). Pure culture strains of *Escherichia coli* and *Aerobacter aerogenes* from 26 different individuals were inoculated into the first three of these media using inocula varying from 1-50 bacteria per tube. In all of 138 strains tested gas was formed in 24 hours of incubation at 37°C. in both plain lactose broth and brilliant green lactose bile medium, while only 71 of the 138 strains or 51 per cent gave as much as 10 per cent of gas in crystal violet broth in 48 hours of incubation. Several strains of coli failed to show growth in crystal violet broth after 5 days of incubation with an inoculum of 1000 or more bacteria per tube. Basic fuchsin broth was found to be still more inhibitive of many strains of coli than crystal violet. Mixed cultures as would usually occur in water samples are more likely to give positive tests in crystal violet broth than is the case when using pure cultures, since it has been shown that in the presence of a fluorescent water bacterium, the fluorescent organism so modifies the crystal violet medium that abundant gas is produced by dye-sensitive strains of *Es. coli* within 30-40 hours of incubation. If the fluorescent organism is grown in the crystal violet broth for 12 hours and the medium resterilized, dye-sensi-

tive coli will produce gas in it within 24-30 hours. The mechanism of this associative action is not clear, however this fluorescent organism has been found to practically decolorize the crystal violet medium within 24 hours, and to cause a definite lowering of the oxidation-reduction potential.

*Effect of Tread upon the Skidding of Automobiles.* J. B. DERIEUX.

Automobile tires of different treads and conditions of tread were placed upon an automobile wheel which was carrying its normal load of seven hundred pounds, and caused to slide, or skid, by pulling with a spring balance upon a lever attached to the wheel, the other wheels being blocked. The following results were obtained:

ROAD MATERIAL	SURFACE CONDITION	HUMIDITY	TREAD CONDITION	SKID FORCE (POUNDS)
Concrete	Smooth	Dry	Good	427
			Poor	469
		Wet	Good	392
			Poor	399
Asphalt	Smooth	Dry	Good	560
			Poor	622
		Wet	Good	475
			Poor	525
Asphalt	Rough	Dry	Good	643
			Poor	700
		Wet	Good	567
			Poor	497
Clay	Smooth	Dry	Good	434
			Poor	434
		Wet	Good	224
			Poor	231
Sand	Loose	Dry	Good	350
			Poor	406
Sand and gravel	Packed	Dry	Good	357
			Poor	371

The tread listed as "poor" was absolutely treadless; it had not the slightest sign of a tread, but the fabric was not exposed. Different "good" treads were observed, but there was only a very slight difference among them. It will be noticed that the treadless tire requires the greater skidding force in practically every case. These values are, of course, for static, or starting skid.

Searching for a reason for the higher value of the treadless, it was thought that probably the greater area of contact of the treadless was the secret. Therefore, the pressure of air in a tire of good tread was reduced in steps, thus increasing its area of contact, and the following results were obtained:

PRESSURE IN POUNDS	AREA IN SQ. IN.	SKID FORCE IN POUNDS
35	13	416
30	15	428
25	18	439
20	23	453
15	30	461
10	45	470

In the first table, for rough, wet asphalt, where the good tread had the higher skidding force, this was probably because the treadless tire had smaller area of contact than usual, being supported by the protruding gravel, and not touching between. However, it may have been that the good tread came into play there, taking hold of the gravel.

#### *Soil Contamination as a Factor in Crop Infestation of Tobacco Mosaic.*

S. G. LEHMAN.

The results of field tests extending over 4 years with tobacco mosaic show that the addition of infected plants to sandy loam soil constitutes a mosaic disease hazard to the crop planted on the land in the next season. Disking the diseased plants into the soil in the fall greatly lowered the percentage of infection from the soil as compared with disking in late spring. Disking was equally as effective as removal of the diseased plants from the land when done in the fall, but removal of the plants was the more effective of the two operations when done in late spring. The production of 4 successive crops of mosaic tobacco on the same land gave no evidence of cumulative increase in the soil of contaminative material effective in production of mosaic infection. The

proportion of initial infections from contaminated soil is low compared to the high percentages of crop infestation observed in some fields at the beginning of harvest. Causes or agencies other than infection from soil must be invoked to explain these high field infestations.

*Studies of the Influence of Vegetative Cover upon Stormflow and Erosion.*

C. R. HURSH.

The author reported measurements of stormflow at 2" and 12" from plots representing four important mountain vegetative cover types: (1) Broomsedge on abandoned farm land; (2) Oldfield pine stand on abandoned farm land; (3) Old growth oak forest; (4) Old growth yellow pine hardwood forest. The report covered a period of one year beginning July 1, 1932. During this period sixty-six individual storms occurred. In order to analyze the stormflow records an arbitrary classification of all storms into 12 groups was adopted, on the basis of total amount and intensity of precipitation for the maximum 20 minute period. The storm classification used was as follows, expressed in 1/100 of inches:

<i>Total amount of precipitation</i>	<i>Maximum intensity 20 minute period</i>
(1) 0-25	(1) 0-10
(2) 26-50	(2) 11-20
(3) 51-100	(3) 21-50
(4) 101-up	

Storms were actually expressed according to a key number to the class. For example, a 2-2 storm indicated a total amount of precipitation of from .26-.50 inches and a maximum intensity of a 20 minute period of .11-.20 inches.

The following summary was presented:

Intensity of precipitation and previous saturation of the soil appear to be the most significant factors influencing stormflow, other than cover conditions.

Vegetative cover types regulate stormflow to a degree that may be considered to be uniformly constant in regard to a definite class of storm based on amount and intensity of precipitation and soil moisture prior to the storm.

Subsurface stormflow may become larger in amount and of more significance in stream regulation than the surface stormflow.

The removal of litter from a yellow pine-hardwood forest area for 3 years has increased surface stormflow 15 to 30 times the control area and has brought about a loss by erosion of 3 inches of mineral soil over

the entire area. Further erosion has apparently been arrested by the formation of an erosion pavement.

*Syncytial Structures Produced by Lymphocytes of Sea Urchins.* IRENE BOLIEK.

Of the Invertebrates the sea urchin<sup>1</sup> proves a favorable form for the study of lymphocyte behavior *in vitro*. Five distinct kinds of lymphocytes are found floating in the perivisceral fluid of the urchin. We are here concerned with but two of these: the leucocytes and the vibratile corpuscles. The leucocyte, as it appears immediately upon extraction of the fluid, is a delicate, colorless cell showing a nucleus ( $6-8\mu$ ) immediately surrounded by a relatively narrow zone of granular cytoplasm and bounded peripherally by a varying number of ectoplasmic flaps or lobes. This cell, however stable it may have been *in vivo*, is very unstable *in vitro*, undergoing constant changes in form: the lobes may be wholly or partially withdrawn, may elongate considerably, etc. Very soon, upon reaching the surface of the slide, these cells take on another habitus, flattening into large thin expansions (laminae) all processes in one plane. The flattened laminate cells may, and often do, fuse to form bi-, tri-, and multi-nucleate masses and often extensive sheets or membranes. All stages in the transformation and fusion of these cells may be found in living and fixed preparations on the slide. Many of the cells with membranous lobes, and in transition phases agglutinate to form aggregates of various sizes.

The question is, what is the behavior of the cells constituting the aggregate: do they fuse as do the cells on the slide, or are they but closely applied, later separating into cells much like those forming the aggregate? Section preparations of larger aggregates which were fixed at intervals ranging from 5 minutes to 7 days all show conclusively that actual fusion between the leucocytes is accomplished, and that the mass breaks up into rounded uni- or multi-nucleate masses only after degeneration has set in. The rounded degeneration masses have no resemblance to the original cellular constituents of the mass.

The vibratile corpuscle or flagellate cell measures  $8\mu$  across and possesses a flagellum 4 times as long ( $32\mu$ ). The flagellum, always

<sup>1</sup> *Lytechinus (Toxopneustes) variegatus* and *Arbacia punctata*, the forms used, were collected off the North Carolina coast, and much of this work was carried out at the U. S. Fisheries Biological Laboratory, Beaufort, N. C. We are indebted to the Commissioner for this privilege and to the Director and staff for courtesies and aid.

described and figured as thread or whip-like is in reality a thin, blade-like structure wider than the cell itself and tapering distally. These cells, like the leucocytes, fuse one to the other forming beautiful reticula, and later syncytia composed of vibratile cells alone. Fusions, however, do not occur immediately upon extraction of the fluid, rather some time afterward, and some of the cells may remain independent and active for days. Section preparations, here as before, bear out the fact that fusions between vibratile corpuscles occur, and that they eventually merge with the general syncytium produced by the leucocytes.

*Economic Possibilities of Pulping Timber Growth of the Coastal Plain.*

E. E. RANDOLPH and W. L. BELVIN.

The coastal plain of North Carolina contains vast areas of low-lying, swampy land covered by forest growth. The land is too low to be drained economically for cultivation and at present has very little value for agricultural purposes. This land is either covered with natural growth or will be available for timber growth which will require very little attention other than protection from forest fires. It seems well to find a way to best utilize the natural resource for the benefit of the people of the eastern part of the state. It is believed that if the natural growth of this area is found suitable for pulping, and a pulp may be produced which will make good grades of paper at a cost which is commercially feasible, some paper company will find it profitable to erect a pulp plant in the eastern part of the state.

Such a project would enhance the value of the lowlands of eastern Carolina, benefit the land owner by utilizing idle lands, tend to promote industrial development of our natural resources, and benefit the state by having land fully utilized in producing the supply for which it is best suited. It would adapt itself to the program of conservation and development of the state, and it would produce timber suitable for pulping in 14 to 20 years, which is approximately four times as rapid as in the northern states.

With this idea in mind the investigation was made on nine species of hardwoods, pulping by the soda process. Chemical analysis of the woods were made, and small scale test cooks were made to determine the ideal cooking conditions. The yield of pulp, ease of pulping, strength of fiber, ease of bleaching, and bleach requirements for each wood was determined.

It was found that the ease of pulping and bleaching of these woods along with the consideration of their fiber length was in the order of



black gum, red gum, sycamore, *Ailanthus*, beech, red maple, black willow, sassafras, and sourwood.

Black gum may be used as a pulp wood at the present time as a filler with long-fibered stock, or as the base stock for forming a sheet where great strength and permanence are not required. Red gum, sycamore, *Ailanthus*, and beech could be used as a filler material as in newsprint. *Ailanthus* may be used as a filler in high grade papers or as a base for blotting and absorbent paper.

It is believed that the present value of pulp and paper would not warrant the use of red maple or black willow because of their short fiber length. Neither sassafras nor sourwood would be feasible for commercial consideration due to their poor pulping and difficult bleaching.

*"Meteor Craters" of the Carolinas.* W. F. PROUTY.

Early in 1933 a field party from the Geology Department, under my direction, began a study of the numerous elliptical bays in the coastal plain portion of the Carolinas. Our field investigation has been largely in central and northeastern South Carolina and southeastern North Carolina. Cross sections of the coastal plain country were run with the magnetometer and many readings taken in the areas of the elliptical bays. During the spring of 1934 Dr. G. R. MacCarthy, J. A. Alexander, and I took further readings in the areas of these bays and elliptical lakes. Our general conclusions concerning these bays and also many of the elliptical lake basins is that they all seem to have the same general mode of origin, as told by their agreement in axial orientation, sand ridge development, and many other features.

The magnetic reconnaissance survey as well as other observations so far made, tend to support the meteoric theory of origin of these bays. A number of the bays have decided "magnetic highs" to the southeast of the depressions. Those near the coast have much weaker anomalies than those further removed from the influence of salt waters. The magnetic anomalies of some of the more inland "bays" are considerably greater than those observed in the case of Meteor Crater, Arizona, where a meteoric body is known to exist.

*The Effect of Fertilization upon Nitrogen Content of a Cecil Clay Loam Soil over a period of 31 years.* E. E. RANDOLPH and G. M. GARREN.

The North Carolina Experiment Station has conducted a fertilizer experiment on the Piedmont Branch Station near Statesville for the past 31 years to determine the effect upon crop yields. Nothing has

been done to determine the effect of such a system upon the latent fertility of the soil. The soil upon which these experiments were conducted is a red clay, officially classified as Cecil clay loam. Two plats, contrasting in fertilizer treatment but from the same series, were selected for comparison of such an effect. Plat No. 8 in field A has received an annual application of a complete fertilizer for the entire period. Plat No. 4 in the same series and distant from plat No. 8 only 87.2 feet received no fertilizer treatment of any kind during the same period. The cropping system practiced upon both was the same. Both plats are 1/20 of an acre in size and both received no lime treatment during the period of the experiments. Plat No. 8 during the period of the experiments received a total of 15.95 pounds of nitrogen, 47.90 pounds of phosphorus pentoxide, and 15.95 pounds of potassium oxide, or potash. The effect upon crop yields was very great in favor of the fertilizer application. To determine the effect upon the latent soil fertility five samples of the soil from each plat were collected at the depths of 8 inches, at a farther depth of 6 more inches, and at the still farther depth of 6 more inches. These different strata are called the top soil, the subsoil, and the sub-subsoil. The five samples collected from each of these different strata were mixed to give a composite sample of the soil of the whole plat at each depth. These composite samples were analysed for total nitrogen with the following results: Top soil of plat No. 8 had .0786 per cent; plat No. 4 had .0756 per cent. There is no practical difference here. In the subsoil of plat No. 8 was found .0653 per cent; in that of No. 4 was found .0498 per cent. Some practical difference here in favor of the fertilized plat. In the sub-subsoil of plat No. 8 was found .0454 per cent; in that of No. 4 was found .0473 per cent. No practical difference here.

These figures show the nitrogen content of these two plats with their contrasting fertilizer treatment after continuous treatment for 31 years. Unfortunately no analyses were made of the soils before beginning the experiments. How much each plat has lost or gained from these contrasting treatments over so long a period can not now be determined. Presumably they were practically the same since they are of the same soil type and located very near each other. Prior to the beginning of the experiments the land had been cultivated under the same cropping systems.

Nitrogen is the most unstable of the mineral plant food elements. Doubtless when the samples are analyzed for phosphorus and potassium greater differences will be found.

*Cell Behavior in the Metamorphosis of the Halichondrine Sponge Larva.*

H. V. WILSON.

The larval epithelium cells of *Mycale syrinx* O. Schm. unite syncytially with one another while side by side. The syncytial stratum so formed is continuous with the syncytial interior of the larva and into this syncytial interior the epithelial nuclei are drawn. Many of the nuclei degenerate and are digested by the syncytial cytoplasm, eventually by nucleolate cells. The syncytial cytoplasm breaks up into cell bodies, some surrounding the epithelial nuclei and thus forming the choanocytes, others surrounding nucleolate and non-nucleolate mesenchyme nuclei. *The larval epithelial cells do not then become the choanocytes.* Only their nuclei are specifically determined. Their cytoplasm merges with that of the general syncytium of the larva, out of which the cytoplasmic bodies of the choanocytes are later picked in accordance only with the location which the nuclei may occupy at the time. Non-nucleolate cells of the interior break through to the surface and form epidermis, as in the current account. Or non-nucleolate nuclei, usually not in special cell bodies but in the general syncytium, are drawn to the surface, the surface layer then condensing to form epidermis. Again it is the nuclei which are specifically determined. The origin of the epidermal cytoplasm is plainly fortuitous.

*What Lies under the Coastal Plain.* G. R. MACCARTHY and J. A. ALEXANDER.

Magnetometer observations made in the coastal plain area of southeastern North Carolina and northeastern South Carolina show the presence of a Triassic basin which is completely concealed by the coastal plain sediments. This Triassic area was previously known only from the logs of two deep wells drilled at Florence, S. C. The magnetometric observations show that the basin is entirely comparable in size to the other similar basins of the eastern United States and that it extends from a point near Sumter, S. C., northeastward past Florence and Dillon, S. C., to beyond Laurinburg, N. C.

*Effect of Some Physico-Chemical Changes in the Environment on Embryo-Formation in the Frog.*<sup>1</sup> JAMES WORKMAN CULBERTSON. (Under the direction of Dr. H. V. Wilson.)

Artificially inseminated eggs of *Rana* and *Chorophilus* were subjected

<sup>1</sup> Title given in program of Academy meeting: *Some Teratological Early Embryos of the Frog.*

to low temperature or weak solutions of sodium chloride or lithium chloride and induced to develop abnormally. The teratological embryos produced can be classified in categories on the basis of morphological affinities and arranged in such serial order that one can observe an initial deviation from the normal course of ontogeny at the beginning of gastrulation and trace its consequences through six successive stages to a familiar condition of spina bifida in a later embryo. Segmentation was caused to vary toward the types represented by *Amia* and *Amphioxus*. The same general type of abnormality can be produced repeatedly with the same agent or widely different agents and sometimes can be found in nature; so, apparently, the chemical only upsets the physiological organization of the embryo. These abnormal embryos employ the same morphogenic processes as normally but often utilize for organ primordia materials which ordinarily would have different fates.

*Some Notes on the Silurian System of Eastern Tennessee.* WM. F. PROUTY and J. G. DOUGLAS.

The Silurian System of the Appalachian Province is greatly in need of revision due to the reconnaissance nature of former work or to the presence of errors which have come to light with the use of more modern methods or because of more complete information pertaining to problems of Paleozoic Geology in general.

The Geologic Society of America is sponsoring this revision and the authors of this paper have undertaken the detailed geologic mapping of the East Tennessee area.

The work has so far resulted in the tentative establishment of certain faunal zones, which it is hoped can be correlated with the work of other investigators to the north and south, and in the correction of certain sections which had previously been erroneously mapped.

Typical sections across Powell Mountain, Clinch Mountain, and Stone Mountain were briefly described.

*The Frogs and Toads of Beaufort County, N. C.* B. B. BRANDT.

1. Twenty-two species of frogs and toads were found to occur in Beaufort County.

2. One of these, *Pseudacris brimleyi*, is a new species.

3. Four others, *Pseudacris n. nigrita*, *Pseudacris ornata*, *Hyla gratiosa*, and *Rana aesopus*, are new to North Carolina.

4. Extensions of range in North Carolina are reported for *Scaphiopus h. holbrooki*, *Bufo quercicus*, *Bufo terrestris*, *Hyla c. cinerea*, *Hyla femoralis*,

*Hyla squirella*, *Pseudacris brimleyi*, *Pseudacris n. nigrita*, *Pseudacris ocularis*, and *Rana virgatipes*.

*The Parasites of the Horned Passalus.* A. S. PEARSE.

*Passalus cornutus* Fabr. was examined each month for a year in the Duke Forest. Parasites are being studied and occur about as follows: crop, *Gregarina* sp.; stomach, *Histrignathus rigidus* Leidy; body cavity, *Chondronema passali* (Leidy); exterior, five or more species of mites—*Euzercon* sp., *Uropodidae*, *Megisthanus floridanus* Banks, *Urosieus* sp., etc.; under elytra, three or more species of mites—*Macrocheles* sp., *Canestriniidae*, etc. A fly larva, *Pseudeuanta coquillettii* Ald., was found in a few of the larvae of the beetles.

*Fossil Whales of the North Carolina Miocene.* W. F. PROUTY.

Fossil remains of Middle Miocene whale have been secured from the St. Mary's formation in North Carolina. The most fossiliferous horizon is in the lower third of this formation which outcrops in a strip extending in a northeastwardly direction from Tarboro. Near the pumping station at Tarboro a nearly complete skeleton was uncovered. The lower jaws were  $13\frac{1}{2}$  feet long. Few of the bones, except the vertebrae and "leg" bones could be saved because of their very fragile character and the frequent "cave ins" of the marl beds from which the bones were taken.

On Kirby Creek near the east line of Northampton County, N. C., are the remains of at least two whales. Nearly perfect cervical vertebrae were gotten from here with portions of lower jaws, ribs and baleen (whalebone). The valley of Fishing Creek, to the north of Tarboro, is also known to be a good whale collecting ground. In all these localities it will be found expensive to get out anything like a complete skeleton as the wet bones tend to fall to pieces on exposure to the air, if much disturbed before they become dry.

*Conics of Fourth Order Contact.* J. W. LASLEY, JR.

This paper consisted of a presentation of simpler forms for the expression of certain parts of the conic having fourth order contact with a plane curve at a point. The form of the equation referred to a local reference frame consisting of the tangent and the normal of the given curve at the point, to the axes on the centre and parallel to this frame, and to the principal axes of the conic were given. Simpler forms for the centre, for the curve of aberrancy, for testing the kind of conic, for

the radius and index of aberrancy, for the angle of aberrance were presented. The equation of the axes of the conic, an expression for the inclination of the principal axis, the differential equation of all conics, and a construction for the conic were given in simpler form than those found in the literature. These results were identified with those forms already known.

*The Equations of Certain Osculants to Plane Curves.* E. A. CAMERON.

The object of the paper is to obtain the equations referred to a general rectangular Cartesian coordinate system of the osculating conic, the osculating parabola, and the osculating equilateral hyperbola of a plane curve. This is done by effecting certain transformations on the equations of these osculants referred to a local reference system consisting of the tangent and normal to the base curve. The coefficients in the equations are functions of the differential coefficients obtained from the equation of the base curve and evaluated at the point at which the osculants are defined.

*The Coefficient of Friction of Rubber.* J. B. DERIEUX.

Coefficient of friction is defined as the ratio of the force of friction to the load producing it. The accepted laws of the coefficient of friction are:

1. It is independent of the area of the surface in contact.
2. It is independent of the load applied.
3. It is independent of the velocity, at low values.
4. The static value is greater than the kinetic, i.e., it is greater at the beginning of motion, than after motion has been established.

The accompanying data will show that every one of these accepted laws are violated by rubber.

The following values for Area were obtained by varying the pressure in an automobile tire in place on an automobile on concrete.

PRESSURE IN POUNDS	AREA IN SQ. IN.	FRICTION IN POUNDS	LOAD IN POUNDS	COEFFICIENT
35	13	416	700	0.59
30	15	428	700	0.61
25	18	439	700	0.63
20	23	453	700	0.65
15	30	461	700	0.66
10	45	470	700	0.67

It will be observed that the coefficient increases with area.

The study of the effect of different loads was made by pulling a piece of automobile tire slowly along a level surface in the laboratory. The following values were obtained:

LOAD IN GRAMS	ON VARNISHED WOOD		ON SMOOTH CONCRETE		ON ROUGH CONCRETE	
	Friction in Grams	Coefficient	Friction in Grams	Coefficient	Friction in Grams	Coefficient
700	300	.428	605	.865	615	.878
900	400	.445	785	.873	805	.895
1100	500	.455	975	.877	1000	.910
1300	600	.462	1175	.905	1230	.947
1500	700	.467	1375	.918	1550	1.064

It is evident that the coefficient increases with load increase.

The investigation of the effect of Velocity was made by timing a piece of automobile tire in sliding with constant velocity down an inclined plane, and taking the tangent of the angle of the plane with the horizontal as the coefficient. (This is a standard method of finding coefficient.)

It was found that rubber moves with a creeping motion down an inclined plane, and that gave the suggestion of the method of attack of the velocity problem. Setting the plane at an angle too small for the rubber to slide, apparently, it was observed to be very slowly creeping down the plane. The angle was increased, and while the rubber moved faster, it was without acceleration. The following data were obtained:

SMOOTH SURFACE					ROUGHER SURFACE				
Plane		Time	Vel.	Coef.	Plane		Time	Vel.	Coef.
Length	Angle				Length	Angle			
cm.	deg.	sec. cm./sec.			cm.	deg.	sec. cm./sec.		
25	18	infin.	0	.325	25	21	infin.	0	.384
25	20	74	.338	.364	25	22½	122	.205	.414
25	22½	20	1.25	.414	25	25	21.6	1.16	.466
25	25	6.4	3.90	.466	25	27½	8.0	3.12	.520
25	27½	2.7	9.25	.520	25	30	2.45	10.2	.578

It may be seen that the coefficient increases with velocity.

The relation of the Static to the Kinetic is obtained from the last

preceding table. The Static value is that for zero velocity, while the Kinetic include all the others. It is clearly seen that the static value is smallest.

*A Preliminary Study of Temperature, Time, and Strain Relationships for Rubber.* MILTON L. BRAUN.

A series of small rubber bands carefully selected from a common source were stretched by respective gravity loads ranging from 100 to 450 grams. Each band had a mass of 0.120 g, a uniform unstretched length, and under the slack-consuming tension of a 50 gram hanger a length of 5.30 cm. The length of each band with its respective load was observed as a function of time. The elongations obtained in twenty-four hours ranged from about 50 per cent to 500 per cent. As might be expected the greater loads produced greater elongations, but the elongation per unit force was a maximum for the 250 gram load. By the one-hundredth day the bands had increased their one day elongation by an additional 30 per cent to 90 per cent of their original length. The maximum increase, however, was not with the greatest load but occurred with that of 200 g. The greatest stretch per unit load was again associated with the 250 gram load. The bands were suspended in a glass door cabinet. Temperature and relative humidity variations were recorded. This work is preliminary to a study of the relation between temperature and strain.

*Intensity of the Electrodeless Hydrogen Spectrum as Conditioned by Pressure and Discharge Tube Dimensions.* MYRON STANLEY McCAY.

The intensities of the hydrogen alpha and beta spectral lines as excited by high frequency, undamped voltages were studied as conditioned by pressure of the gas and diameter of the discharge tube. The values of the intensities of each line were found to pass through definite maxima between pressures of 30–200 microns in a similar manner to the change of conductivity in the discharge. The pressure of these maxima was shifted to higher values by decreasing the diameter of the discharge tube. An explanation of the determined effect of tube dimensions on these maxima has been developed.

H. L. BLUMQUIST,  
Secretary.



# PROCEEDINGS OF THE ELISHA MITCHELL SCIENTIFIC SOCIETY

OCTOBER 10, 1933, TO MAY 8, 1934

346TH MEETING, OCTOBER 10, 1933

C. D. BEERS: *Population Studies in Infusoria.*

Published in full in *Archiv fuer Protistenkunde*, Vol. 80, pp. 36-64, 1933, under the title "The Relation of Density of Population to Rate of Reproduction in the Ciliates *Didinium nasutum* and *Stylonychia pustulata*," which see.

W. DEB. MACNIDER: *The Resistance of Fixed Cells to Injury.* (Lantern.)

347TH MEETING, NOVEMBER 14, 1933

The Society celebrated the fiftieth anniversary of its founding at a special meeting held in Gerrard Hall with Dr. J. W. Lasley, Jr., presiding. The program follows:

ARCHIBALD HENDERSON, Kenan Professor of Mathematics: *A Sketch of the History and Achievements of the Society.*

Published in full in this issue.

W. C. COKER, Kenan Professor of Botany: *Publications and Exchanges of the Society.*

IVEY F. LEWIS, Miller Professor of Biology, University of Virginia: *Adaptation, The Fourth Property of Protoplasm.*

Published in full in this issue.

348TH MEETING, DECEMBER 12, 1933

J. M. VALENTINE: *Environmental Response and Evolution in Ground Beetles (Carabidae).*

Field studies in western Europe and northern Africa under diverse ecological and climatic conditions have yielded data of some value in

determining the direct or indirect effect of radiant energy (light and heat) upon the coloration of carabid beetle populations.

Deficiency in either heat or light inhibits pigmentation, portions of the body, such as the legs and elytra where the chitin is weakest, often remaining pale or piceous. Complete depigmentation occurs only in subterranean and cavernicole types.

As available radiant energy is increased, there seems to be a critical point at which full pigmentation is allowed but at which no stimulus is offered for the evolution of a microsculpture capable of diffracting light. Insects subject to these conditions are, for the most part, strictly nocturnal species hiding in dark places by day and are black.

Correlated with a greater exposure to the sun's energy, and with the choice of progressively more open habitats, a long series of corresponding color stages may be assembled, from the dark metallic and dull parti-colored forms of crepuscular habits, concealed in the forest by day under loose cover, to the brilliantly hued species active in the open sunlight.

A broad consideration of these tendencies has led to the theory that adequate radiant energy above a certain critical point is necessary for the full release of the genetic potential stored within the race. Carrying this idea a little further, it is suggested that the relatively great diversity in form and color characteristic of tropical insects is the result of an actual stimulating effect which mutational forces sustain in environments reached by the equatorial sun.

The release of genetic potential has been found to be by no means a random affair. Wherever an environmental factor, such as a homogeneous substratum, is found to be predominant, it becomes indirectly reflected in the appearance of the carabid population inhabiting that ecological frame. The result is convergent evolution. It is thought that all problems of parallelism including mimicry and insular convergence have, fundamentally, a great deal in common, though no analysis of the factors involved has yet proved satisfactory.

T. F. HICKERSON: *Continuous Beams and Frames: A New Method of Analysis.*

349TH MEETING, JANUARY 9, 1934

H. D. CROCKFORD: *Some Problems in the Operation of the Lead Storage Cell.*

W. F. PROUTY: *Mineral Resources of the Tennessee Valley Region.*

The basin of the Tennessee River drains practically all types of rock areas in the five physiographic provinces which it traverses. It thus has a great variety of soil, topography, climate and mineral products.

In the Blue Ridge physiographic province it possesses the greatest variety of minerals in association with the igneous and metamorphic rocks. Here, chiefly in North Carolina and Georgia, we have the greatest known feldspar—kaolin—mica deposits associated with the pegmatites. This area leads the world in the production of feldspar and the United States in the production of mica. It is fast becoming a leader in the production of high grade ceramic materials. Magnetic iron ore, together with chromium, nickel and copper ores, are found in considerable quantities in this area. Many rare and semi-precious minerals are also associated with the numerous pegmatites.

The Appalachian Valley Province with its stratified sedimentary rocks has a large variety of useful minerals in workable quantities. Barite, so much used for paint, occurs in large deposits in Virginia, Tennessee, North Carolina, Georgia, and Alabama. Bauxite, the chief ore of aluminum, is also found in workable quantities in several places in Tennessee, Georgia, and Alabama. Both limonite and hematite, ores of iron, are widely distributed and have furnished raw materials for iron manufacture in a number of places as at Rockwood and Chattanooga. The zinc deposits are especially well known in the valley northeast of Knoxville. This area has been a heavy zinc producer for many years. Some of the less valuable zinc deposits will be buried in the reservoir created by the Norris Dam. The marble deposits about Knoxville lead the world in marble production.

The Cumberland Plateau Province is almost entirely underlain by coal deposits and fire clay. The coals are of greater thickness and better quality in the northern portion of Tennessee and adjoining Virginia areas and again toward the south in the Warrior Coal Field of Alabama. In some localities of Tennessee and southeastern Kentucky there are workable deposits of both petroleum and natural gas.

In the Interior Plains Province of Central Tennessee and Kentucky are located the great brown, blue and white phosphate deposits which yield, next to the Florida deposits, the largest production in the United States. On the south side of the Tennessee Valley in northern Alabama and in the Bowling Green area of Kentucky are vast areas of rock asphalt deposits much used throughout the country in road construction. Near the mouth of the Tennessee River in Kentucky and across

the River in Illinois are found the greatest known fluorite deposits of the world. These deposits are accessible to both water and rail transportation. Manganese, bauxite, oolitic limestone, and brown iron ores are also to be found in important deposits in this province.

The Tennessee Valley occupies a portion of the Coastal Plain Province in North Carolina, Mississippi, Western Tennessee, and Southwestern Kentucky. In this area occur large quantities of very high grade clays, including the "ball" clays so much used in the ceramic industries, vast gravel deposits which have been shipped for many years from northeastern Mississippi to many parts of the United States, and bauxite deposits extending down into eastern Mississippi of considerable importance.

It would be very difficult to find an area equal to that of the Tennessee Valley anywhere in the world which contains as many different types of mineral deposits of as great importance to civilization as are to be found in this one watershed. The term which has sometimes been applied to the Tennessee Valley as "the American Ruhr" seems justified.

W. F. PROUTY: *Carolina Bays*.

The elliptical depressions locally called "bays" in the Carolinas have been studied in recent months by W. F. Prouty, G. R. MacCarthy and J. A. Alexander of the Department of Geology, University of North Carolina, under the research fund of the Rockefeller Foundation. A careful study of all available maps shows a vast number of these elliptical depressions having the same direction of elongation and apparently the same mode of origin. The areas in which these depressions are most abundant are the Coastal Plain portions of the Carolinas and northeastern Georgia. There are a few scattered depressions as far north as southeastern Virginia. These bays are best shown on aerial photographs but their presence is indicated on many topographic and some of the soil survey maps. Other soil survey maps have not the slightest indication of their presence, although hundreds of these depressions, of as much as one-half mile diameter, are known to occur in the area of such a map. It is thought that a number of the lakes in North Carolina, as, for example, many of those in Bladen County, have the same origin as the elliptical bays.

The chief purpose of the survey was to determine; if possible, the origin of these bays. Careful magnetic studies have been made on a number of these bays in different parts of the area. The bays near the coast were found to have very small magnetic anomalies but some well

inland show sufficiently large anomalies to warrant the possibility of a buried meteoric body below and to the southeast of these depressions. Further work on this problem is anticipated. While there is a general uniformity in the direction of elongation of the elliptical depressions, there seems to be a tendency for those toward the north to have more of an east-west trend, while those to the south may have more of a north-south trend, thus indicating what might be expected from a flock of meteoric bodies,—a slightly radial distribution due to the increased air resistance in the front of the swarm. The conclusion is reached that the origin of these bays is meteoric although this origin cannot as yet be absolutely proved.

350TH MEETING, FEBRUARY 13, 1934

E. S. BARR: *Infra-red Study of Some Inorganic Acids.*

A. M. WHITE: *The Power Consumption of Agitators.*

Published in full in the Transactions of the American Institute of Chemical Engineers, 30: 570-596, under the title "Studies in Agitation, IV and V."

351ST MEETING, MARCH 13, 1934

J. U. GUNTER: *Anatomy of Venous Valves.*

In this paper a survey of the literature dealing with venous valves was presented. The history, physiological significance, embryology, gross and microscopic anatomy, variability, and distribution of the valves in the human body were considered. The object of this study was to attempt to determine whether mechanical factors or whether hereditary factors were more important in causing valves to develop in veins. It is a significant fact that valves are always absent in certain veins particularly those of the trunk, and are always present in certain others. Several hypotheses for the formation of venous valves were presented, but none was proved.

R. E. COKER: *Reactions of Copepods to High Temperatures.*

Published in full in this issue.

352ND MEETING, APRIL 10, 1934

E. N. KJELLESVIG: *Trenton Foraminifera from New York.*

See abstract in "Preliminary List of Titles and Abstracts" of papers presented at the 46th annual meeting of the Geological Society of America, Chicago, 1933, p. 75.

OTTO STUHLMAN, JR.: *Electrodeless Discharges in Gases.*

Hydrogen was excited as an electrodeless discharge in a high frequency electrical field. A 2 cm. cylindrical electrodeless tube was placed coaxially in a solenoid excited by a dynamically balanced push-pull oscillator. Frequency range 5.0 to 7.5 mega-cycles. Power supply range 10 to 100 watts. Pressures near 250 microns. Intensity of the alpha and beta lines was determined photographically. At constant power input and constant gas pressure the intensities per unit field strength were found to be proportional to the frequency of the oscillating electrical field.

$I_{\alpha}/\beta I$  is equal to 0.976 at 60 watts, 0.986 at 70 watts, and 1.05 at 80 watts.

## 353RD MEETINGS, MAY 8, 1934

COLIN CARMICHAEL: *Heat Transfer from Internal Combustion Engine Cylinders.*

The gas film which adheres to the inside wall of an internal combustion engine cylinder offers a high resistance to the flow of heat and effectively protects the wall material from the high flame temperatures attained during combustion, provided a sufficient flow of heat is maintained.

An analytical study based on the Kinetic Theory of Gases and Dimensional Analysis shows that the film coefficient of heat transfer is affected by viscosity, density, specific heat and velocity of the gases inside the cylinder. When the first three variables are expressed in terms of temperature and pressure changes the probable limits of variation during a cycle are determined.

Numerical values of the coefficient for any engine or type of engine under any conditions must be determined by experiment, and it is proposed to base calculations on the average temperature throughout the cycle and on the average rate of heat transfer. This is necessary since it is not possible to follow the rapid temperature changes during a cycle inside the cylinder with any existing instruments, and the rate of heat transfer from the cylinder can only be found by measuring the cooling water flow over a finite period of time.

Experiments conducted on a gasoline engine show the effect on the heat transfer coefficient of changes in spark advance, air-fuel ratio, speed and throttle opening. It is concluded that turbulence and high pressure are chiefly responsible for high values of the coefficient, while the presence of carbon deposit decreases the coefficient.

J. W. LASLEY, JR.: *Recent Developments in the Differential Geometry of Plane Curves.*

The following officers were elected for the year 1934-1935:

*President*—G. R. MacCarthy.

*Vice-President*—R. W. Bost.

*Secretary-Treasurer*—E. W. McChesney.

Dr. E. T. Browne was elected Permanent Secretary of the Society. The editors of the Journal, W. C. Coker, H. V. Wilson, and Otto Stuhlman, Jr., continue in office.

The following resolutions were submitted.

James Munsie Bell died March 3 at Clearwater, Florida. To his bereaved family the Elisha Mitchell Scientific Society extends its very deep sympathy. We, too, are bereaved of a friend, and are acutely sensible of the loss of an investigator, scholar, teacher, and administrator, who attained rare success in each of these fields; who united with the attributes required for these successes, a broad interest in science other than his specialty, wide culture, bibliographical skill, and an unending enthusiasm for the interests of this Society. As Permanent Secretary for years, he labored steadfastly for the enhancement of its prestige, its usefulness, and whatever appeared as its interests. Our indebtedness to him can never be repaid, but we gratefully acknowledge it.

Dr. Bell was born at Chesley, Ontario, Canada, in 1880. At the University of Toronto he received his A.B. in 1902 and his A.M. three years later. He was Sage Fellow at Cornell University and received his Ph.D. in 1905. For the next five years he worked at the U. S. Department of Agriculture on physico-chemical problems in the genesis of soils, reclamation of alkali soils, and fertilizers, the results of these researches being recorded in a number of governmental publications and journal articles. Coming to Chapel Hill in 1910, he later published the results of investigations on the heat capacities and other properties of the nitrotoluenes, on concentration cells, free energy and heat capacities, copper salts, and other problems of more transitory interest. He is more widely remembered perhaps by his work on the compounds of zirconium, part of which was done in collaboration with Dr. Venable. In collaboration with Dr. Paul M. Gross he published a widely used text book on physical chemistry. Called to head the Department of Chemistry in 1921, he further assumed the duties of Dean of the School of Applied Science in 1929, and throughout these succeeding years he was an active member of various administrative and other faculty com-

mittees. Dr. Bell was a member of the leading chemical societies, the North Carolina Academy of Science, Sigma Xi, Alpha Chi Sigma, and was Permanent Secretary of the Elisha Mitchell Scientific Society, an unique honor.

In 1909 Dr. Bell married Miss Mary E. Brawner, of Georgetown, D. C., who survives him, as does his mother, Mrs. Hannah M. Bell of Toronto, Canada.

Your committee offers this statement as a resolution, to be spread upon the minutes of the Society with instructions to the Secretary to forward a copy to the bereaved family.

JAMES B. BULLITT,  
FRANK K. CAMERON,  
ALVIN S. WHEELER.

Francis Preston Venable passed from this life March 17, 1934, ending a long, useful life of unusual distinction. Always with dignity, he was ever ready to aid others to the limit of his great abilities. Particularly his life concerns were the helping of the youth of the South to better educational opportunities. Honors, memberships in organizations, and positions of trust, were to him always calls to service, and he never failed to give it. In his own special field of chemistry he united a marvelous manipulative skill with a penetrating insight which led to a number of investigations, his work on zirconium and its compounds having become classical. His expository powers were unusually fine and led to a series of texts on various special fields of chemistry always with the result that what was obscure to all but a few specialists became clear and intelligible for all students.

He was born in Prince Edward County, Virginia, November 17, 1856. After a childhood in South Carolina, he went with his family to Charlottesville, Virginia, where his father, a distinguished mathematician, was a member of the faculty. Venable's tastes lay in another direction, and under the tutelage of Mallet, he acquired a laboratory technique which determined his career as an experimentalist in chemical problems. Leaving the University of Virginia in 1879, after a year in Bonn, he received a Ph.D. at Göttingen in 1881. Eight years later he spent a year of study at Berlin. Meanwhile he had come to Chapel Hill, in 1880, and, with very sketchy equipment and resources, began the organization of a department of chemistry which now has eight professors, and a fine equipment housed in a modern laboratory, Venable Hall, named in his honor. In 1900, regretfully, for it seemed to be the



end of his career as a scientist, he responded to the call of duty and assumed the presidency of the University, a load he carried for fourteen fruitful years. His health badly jeopardized, he retired for a short period of recuperation, but soon returned to assume the duties of a professor in the department of chemistry. In 1930, after a half century of service, he was made professor *emeritus*, gradually gave up active work and lived in complete retirement the last year or two.

Venable was vice-president of the American Association in 1899 and president of the American Chemical Society in 1905. He was a member of the Philosophical Society, the London Chemical Society, the Elisha Mitchell Scientific Society, the North Carolina Academy of Science, the Advisory Committee of the Chemical Warfare Service, and many other organizations in whose work he took an active part. He was made an honorary Doctor of Science by Lafayette, and the degree LL.D. was conferred on him by Jefferson Medical College and the Universities of Pennsylvania, South Carolina, and Alabama.

The Elisha Mitchell Scientific Society realizes it has suffered a great bereavement. It extends its deep sympathy to his family. To his colleagues, his associates, and a veritable host of students who have felt the beneficent influence of his teaching and example, he will long be held in grateful memory.

F. K. CAMERON,  
I. H. MANNING,  
H. V. WILSON.

## GALLS AND "GALLS"

By B. W. WELLS

In choosing this subject dealing with the field of cecidia or galls, it may be made clear at once that the primary purpose of this paper is to point out the unique character of the higher galls, and to show that in contrast to the lower forms the higher galls are not pathological structures in the same sense that the lower ones are. The term "gall" implies an "excrecent" or "diseased" nature, qualities which are wrongly ascribed to the perfectly normal organism structures of the higher galls. Thus we shall attempt to show that biologists must deal with galls and "galls."

So many notable discoveries in science have been made through a study of the exceptions to the rule that a neglected exception should in turn become notable. The field of galls has throughout the history of the biology of growth constituted such a neglected exception.

We desire to present the remarkable exception in morphogenesis which biologists face in the field of the higher insect galls or zoocecidia (proso-plasmas of Küster) where an amazing array of form and tissue orientation characters are expressed in plant cell aggregates under controlling stimuli of unknown nature and with no chromosome continuity occurring between the animal and the plant.

To throw this problem of the higher galls into the relief desired it will be well to refer to a particular kind of character and its inheritance in a common plant structure and contrast this with a similar kind of character in the galls.

The genetics of the shape character in squashes has been studied by Sinnott (6). To quote:

It is obvious that the specific shapes so characteristic of organic bodies and their various parts are as readily transmitted from parent to offspring by the processes of inheritance as are any other traits, but little is definitely known as to the mechanism by which this is accomplished. The problem is of particular biological interest since the persistence of these specific shapes is one of the most distinctive attributes of living organisms. Evidence is accumulating from various sources that shape inheritance is controlled by genes similar in character to those which have been postulated for other traits.

Although shape characters thus seem to present nothing unique in their inheritance, they are necessarily related more intimately to the processes of growth and development than are many other traits. The production of any specific shape must require a highly coordinated control over growth, but the means by which such control is exercised are quite beyond our present knowledge.

Contrast the expression of shape in squashes with the problem presented in the higher galls, where in a single genus may be found a series of species and varieties which presents a much wider range in number and qualitative differences of shape than is shown in the squashes. To be specific, on a single leaflet of hickory a series of itonid (*Caryomyia*) galls may often be found which will rival in diversity and constancy the shape variations in squashes. It should be noted that for these species of galls, the story of the final attainment of these specific shape characteristics is just as definite a one and presents the same problem in heredity and development that squashes do.

The question may now be raised as to the genes controlling these shape diversities. The cells of the young hickory leaflet from which the gall arises presumably all have the same gene content. We certainly are not to imagine that at certain points on the leaflet the chromosome content varies and that the larvae after oviposition find these variables and stimulate them to develop the specific galls. Such an approach even to a geneticist would be biological nonsense. The most casual survey of a higher gall series on a single leaf points to but one place as the immediate primary origin of gall form, and that is to the fertilized eggs producing the larval gall makers. Using the gene theory of Sinnott and geneticists generally, in relation to shape, the morphogenesis of the gall is determined at fertilization of the animal egg cell—yet the shape character is expressed in plant tissues with no chromosome continuity whatever, being involved.

One fact certainly which is common to shape development in the squashes and the galls is that nothing whatever is known about the mechanism of their growth or ontogenesis. Yet it is interesting to have clearly in mind that in the case of the former, chromosome continuity is present, and the case of the latter entirely absent.

We are by no means confined to the shape in this peculiar mode of character expression. Contrast in your minds the very familiar oak apple galls, the more primitive spongy one (*Amphibolips confluens*) with the more highly evolved one having radiating fibers suspending the larval cell at the center (*A. inanis*). Here is a contrast in cortical layers

that is wholly assignable to a difference in the hereditary composition of the insect larvae initiating these diverse galls. It would be needless to mention the fact that both of these galls may be found to be neighbors on a number of the trees of a number of species of the red oak sub-genus where they have developed from very young leaves, the larvae initiating the galls before the buds have opened.

One more character may be used to illustrate the principle to be observed here of ontogenesis without chromosome continuity. In the hackberry dipterous galls as well as others one may observe definite and consistent differences in the orientation of tissues (Wells, 9). The course of the vascular bundles may be very different in different galls. In one, for example, the bundle traverses the stereome layer of thick-walled cells while in another, it remains external to it. In these galls the orientation of the thick parenchyma regions is entirely different,—proximal vs. distal. In other related forms, especially the one developing wings, the bundle orientation is unique. The very familiar stereome or so-called protective layer shows diversity in orientation and an astonishing variety of forms.

Because of the genetical aspects of the sex problem, a brief mention should be made of certain remarkable Australian galls which are "male and female"—at least they differ according to the sex of the gall maker.

In the higher galls as has been shown in the instances just presented, we have an organic structure made up of plant cells but which goes through a perfectly normal growth to the final expression of a cluster of specific characters, many of the most important of which have no relation whatever to the plant as far as their origin is concerned. The exact similarity in the fundamentals of ontogenesis that the higher galls bear to normal, specific organisms indicates that biologists have long misunderstood their essential organismal nature. To deal with them as pathological responses of the plant is to confuse them with truly pathological entities. It is not in the nature of diseased structures to go on developing and evolving as well into that peculiar perfection of generic and specific structure observable everywhere in normal organisms.

It may have been noted that the phrase "higher galls" has been used for the structures thus far presented. This has been intentional since the expression "lower galls" should be reserved to distinguish the true galls; i.e., galls in the sense associated with the name; i.e., of diseased and malformed plant organs.

Küster (5) the great authority on pathological plant anatomy very clearly saw this fundamental cleavage dividing the gall group, calling

the lower galls "kataplasmas" and the higher galls "prosoplasmas." He defined them as follows:

Kataplasmas are those galls which are characterized by inconstancy and indefiniteness with regard to size and tissue form characters; there is also associated an indefinite time element; they invariably fall below corresponding normal parts in their differentiation, and what differentiation does ensue shows no new fundamental orientation of tissues as contrasted with the normal arrangement; Prosoplasmas are those galls which are characterized by definite size, tissue form, and time of development; in their differentiation they are not so much below the normal as they are different from the normal; in their form characters and orientation of tissues they are fundamentally different from the normal; they may be different in other characters as well, such as quality and quantity of organic substances contained.

In the mind of the writer this distinction is basic to any true understanding of the science of cecidia. Küster who so clearly saw the line dividing the galls into these two groups, yet failed to follow the logic dictated by ontogenetic criteria and recognize the prosoplasmas, (so far certainly as morphogenesis is concerned) as the result of the evolution of a definite morphogenetic mechanism comparable to that functioning in ordinary organisms.

This conception may be made clearer in contrasting the prosoplasmas or the higher galls already presented with examples of the lower galls (kataplasmas). The lepidopterous galls, chiefly stem enlargements, are of this type. Truly pathological, the stem enlargement is largely due to a suppression of the normal degree of differentiation; weak bundles traverse the gall area and the larger amount of parenchyma shows cellular hypertrophy. No new gamut of specific shapes appears in these cases associated with a range of species; they are merely slight but abnormal modifications induced in the stems—modifications which result in a simplification of structure through an inhibition of differentiation. In the bacterial induced crown gall where active cell proliferation occurs we have an excellent example of a loose essentially formless type of structure having no specific shape which may be correlated with the organism. Such a gall is a truly pathological product of hyperplasia and hypertrophy—a structure failing to attain the normal differentiation of the plant part much less develop into a new form and orientation of tissues.

The typical higher gall is appendicular. It has originated either from meristematic tissue or what is more commonly true from a meristematic

tissue which has been dedifferentiated, so to speak, from semi-differentiated tissues of leaves and stems. Through rapid cell proliferation set up by the larval control, the partly specialized cells lose all of their distinctive appearance and as a local mass of newly organized meristem, surge forward in growth and under the continuing larval control go through a completely new ontogenesis to the final definite and specific higher gall.

In such a gall the characters are so consistently to be correlated with the insect producing it that the gall is uniformly given the name of the insect. An authority on the *Cynipidae*, like Kinsey (3), uses the galls constantly as a guide in collecting. This student in his studies of long-winged vs. short-winged forms in the *Cynipidae* (oak gall makers) found the galls extremely valuable in making judgments as to relationship. He states that because "gall structures are significant measures of an inherited physiologic capacity of the insects," that the "utilization of gall characters may be cited to show the connection of the long-winged *Cynips nubila* with the short-winged *pezomachoides*. *Nubila*, occurring in the Southwest, produces a large, wool-coated gall which is superficially as different from the small, naked, faceted gall of *pezomachoides* as one might conceive. However, among the close relatives of *nubila* is the long-winged *acraspiformis* which we have just shown is close to the short-winged *alaria* and *villosa*. If reference is made to the figures of the details of gall structures of these species, one may find an interesting transition from the galls of the long-winged *nubila*, *expositor*, and *acraspiformis* to the galls of the short-winged *prinoides*, *erinacei*, and *macrescens*. The last two of these are naked, faceted galls of the *pezomachoides* type. Further consideration of the plant tissues which enter into these gall structures shows that the same elements are involved in all these galls, and that these elements are developed nowhere but in the subgenus *Acraspis* of the genus *Cynips*. Thus even such superficially diverse galls as those of *nubila* and *pezomachoides* evidence the close affinities between short-winged and long-winged species of insects."

It may seem strange that this discussion could have proceeded so far without bringing in the stimulus problem. The best reason for not bringing it in is that we know nothing about it—and the same is equally true for squashes according to Sinnott. In other words the ontogenetic or growth mechanism everywhere in nature still constitutes next to evolution the major puzzle in biology.

For the reader's information however, a brief summary of the various kinds of stimuli which have been suggested by different writers will be in order.

The original suggestion as to stimulus was that of Malpighi, who in his *De Gallis* (1686) stated that at the time of oviposition, the mother insect introduced a gall-making substance into the plant. This superstition appears even today in books as "produced by the sting of an insect." Adler and others emphasized mechanical factors such as the biting action of certain larvae and the possible use of the fifth segment chitinous appendage in the case of itonid larvae of the diptera. One of the most unique ideas is that gall development is under the control of these new and mysterious mitogenetic rays which have been shown to be emitted by certain living bodies. If this is true, these rays must be very potent in proportion to their strength for Scherewschewsky has shown that they cannot be recorded on the finest ray detector.

The preponderance of opinion among recent students is that some form of complex organic substance or substances is given off from wounded cells, egg surface, or from some part or all of the larvae. Among such substances suggested are cell disintegration products, toxins, hormones, lytic substances, enzymes, and antigens have all been mentioned as possible factors in the so-called stimulation of cecidial development.

The latest of the hypotheses along these lines to be put forward is the antigen-antibody theory of Kostoff and Kendall (4). Their conception is significant only in showing how easy it is to arrive at absurd conclusions when building upon insecure foundations. These workers in the field of plant immunology with no grasp of the implications to be derived from zoocecidial systematics, naïvely attempt to apply the "foreign substance-plant reaction" concept to the higher galls. This attempt is a failure since the sequence of events takes place wholly in the imaginations of their authors—no experiments are reported which would support their claims in the field of the complex oak galls, which they merely described. One of their corollaries was the explanation of the sclerenchyma or stony layer which is so frequently present in galls. This zone represents for them the "product of plant reaction where the interaction between foreign substances and the plant protective substances take place." So real does this theory become that sclerenchyma in the plant originates in this manner for they go so far as to state: "One may correlate the abundance of sclerenchyma cells occurring in the cortex of dicotyledonous plants where they develop by sclerification of the thin-walled parenchyma, with the fact that the bark represents the region exposed during the whole life of the plant to the attacks of bacteria, fungi, etc." One has but to imagine how well trained the bacteria and

fungi must be to so regularly introduce their foreign bodies as to produce the symmetrical designs of cortical sclerenchyma which occur in linden twigs for instance, to see the complete absurdity of such a conception. Again had these authors known galls better, and had some broad knowledge of the variation in shape and distribution of these sclerenchyma layers, they would never have put forward such a simple diffusion-action and reaction hypothesis as this one.

In closing this criticism of the theories of Kostoff and Kendall, attention should be called to a statement by Chester (1) in his monograph on "Physiological Immunity in Plants": "The effects described by Kostoff, gall formation, abnormal meiosis, corolla and calyx deformity, etc., are highly suggestive of environmental conditioned characters rather than specific antigen-antibody effects." Chester and Whitaker earlier had shown that Kostoff's claims of precipitin reactions in the Solanaceous plants were in error and non-immunological in character and due to the non-protein substances normally present in these cells.

Again it may be emphasized that we are as ignorant of how a higher gall is produced as we are of the development of a squash.

The discussion thus far has been centered around the problem of gall ontogenesis. We may also deal with galls phylogenetically as well. In a paper by the writer (Wells, 11) entitled the "Evolution of Zoocecidia," the higher galls were for the first time treated from the standpoint of phylogeny. The major evolutionary movements were outlined and the relation of the higher galls to the lower were indicated. In the summary of this paper the following generalization was made:

Kataplasmic evolution is held to be a process of progressive inhibition of differentiation ending with tissue homogeneity. Prosoplasmic evolution may only begin when homogeneity has been attained, and consists in the development of new form and tissue orientation characters chiefly. In prosoplasma formation, whether viewed ontogenetically or phylogenetically, the insect larva has gained control of the differentiation and morphogenetic mechanisms, so that animal factors come to expression in plant tissue.

Many studies since that time have supported this concept. Of especial significance because of the remarkable breadth and scope of the work is the book of Kinsey already mentioned dealing with the cynipid galls. In his entomological classification of the genus *Cynips*, Kinsey finds six subgenera. As to the correlated galls he writes:

Within each subgenus there is striking uniformity in the degree of development of each gall tissue. Thus, in the subgenus *Cynips* the



protective layer is unusually thick and the collenchyma layer is absent or poorly developed (except in the unique *C. cornifex*). In *Antron* all five layers are well developed, with a more pronounced development of the collenchyma layer. In *Besbicus* all five layers are again present. In *Philonix* the development is chiefly that of a rather solid spongy parenchyma. In *Atrusca* it is a parenchyma with few but tremendously extended fibers. In *Acraspis* all five layers are developed among the species centering about *Cynips mellea*, but in the other specific stocks in *Acraspis* the protective and parenchyma zones seem absent and the collenchyma and epidermal layers are unusually well developed.

The gall-producing stimulus, whatever its origin, is evidently selective in its effects upon particular plant tissues; and, since the gall characters are usually of subgeneric significance, it is apparent that these peculiarities of the gall-producing stimuli are of as ancient standing as any of the morphologic structures of the insects. This means that these physiologic qualities have been constant in heredity for possibly ten or twenty million years during which the specific stocks of *Cynips* have been differentiated.

Again in relation to an example of differing galls associated with non-differing insects Kinsey correctly states: "These stocks (*Cynips maculosa* and *C. mirabilis*) have been separated since early in the history of the subgenus, but it is certain that most of their evolution has involved physiologic capacities of the insects."

We have discussed the higher galls from the standpoints of ontogeny and phylogeny and have found that they, in certain characteristics, fall into our concepts of these processes just as do normal parts or appendages of organisms with the control always emanating from the animal protoplasm.

Of especial interest at this point is the observation of Mangold (7) in certain embryological experiments. This student found that a piece from the dorsal side of the blastoporic lip of an amphibian gastrula when transplanted to the underside of another gastrula exercised a control of development of the other tissue since there appeared in the latter, a secondary embryonic primordium. Such directive portions of tissue have been called by Spemann (8) and others "organizers" and the germ regions in which these organizers lie, the "organization centers." Further, organizers may exert their effects in embryos of distant species. An organizer of a toad has been capable of producing a secondary embryonic rudiment in a newt embryo.

These data also indicate that the location of the primary organizer is already determined in the fertilized egg.

Bertalanffy in his "Modern Theories of Development" makes the

comment regarding these experiments that "It is not something already preformed in the material which is awakened but something is prescribed to the latter."

These facts naturally are of great interest in relation to our cecidial problem. The application is evident without further elucidation.

Before bringing this discussion of basic concepts to a close, mention should be made of Wolff's (12) curious theory that in cecidial development we really have a symbiosis in the following manner: The plants have succumbed to the gall-making proclivities of the insects, since to do so resulted in a higher survival rate thanks to the food and protection offered by the galls. The insects through this improvement in their life status were relieved of the necessity of producing many offspring to keep the races going. This resultant decrease in progeny benefits the plant through a lessening in the gall number. Such a theory is devised wholly upon teleological thinking and should be given no credence whatsoever.

From the standpoint of nutrition the gall as well as the insect is a parasite. No theory of symbiosis of any sort may be developed concerning them.

#### SUMMARY

The higher galls show us that a biological mechanism of differentiation exists which is independent of chromosome continuity. So much emphasis is placed upon chromosomes and their genes as the bearers of hereditary qualities that the uncritical student is apt to think of the chromosome mechanism as an essential one to growth. Doubt has long been thrown on the importance of chromosomes in growth since through the equational division of those bodies in the growth mitoses, there is no chance of differentials entering in; all the ultimate cells are copies of the first, chromosomally considered. Gall studies confirm the affirmation that shape and many other characters may come regularly to expression in plant tissue, yet the evolution and ontogenetic origin of the characters have been the function of animal protoplasm. The facts mean exactly that and no less.

For the researcher the higher galls furnish notable exceptions in growth—just the kind of variations he should be hoping for in his attack upon one of the profoundest of all mysteries. With some new refined technique in the study of hormone-like substances, or perhaps a still more refined attack in the subtle field of bio-radiation such a worker may solve a part at least of the awful engima of differentiation.

Until the day when ontogeny is to become an open book, we may at least be aware of these notable exceptions in the living world which we recognize as the higher zooecidia or prosoplasmas. Or stated more simply this awareness means that we must recognize galls and "galls."

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# CONTRIBUTION TO KNOWLEDGE OF NORTH AMERICAN FRESHWATER HARPACTICOID COPEPOD CRUSTACEA<sup>1</sup>

By ROBERT E. COKER

PLATES 1-15 AND 9 TEXT FIGURES

## INTRODUCTION

Though the great number of species of copepods are assigned to many families, it happens that free-living copepods of fresh waters fall into but three groups, lying in three of the seven divisions, or suborders, into which Sars has divided the Eucopepoda. These groups, formerly called families, are readily distinguishable at a glance, and they are almost as clearly differentiated in habit as they are in structure. First, there are the centropagids (part of the Calanoida), with bodies divided distinctly into two parts called, respectively, cephalothorax or cephalosome, and abdomen or urosome, with very long, many-jointed antennae and with mouth parts adapted for straining food from complex currents that they maintain both while at rest and when in slow movement; these "drifters" (or treaders of water) and filterers are characteristic of open waters of lakes, large ponds, and slow rivers. There are also the cyclopids (of the Cyclopoida), with the last thoracic segment more firmly joined to the abdomen than to preceding thoracic segments (so that cephalosome and urosome are no longer strictly synonymous with cephalothorax and abdomen), with antennae of moderate length (not more than 17 segments) and with mouth parts adapted for biting; a few of these active swimmers and pursuers of prey, swimmers and seizers they may be called, live pelagic lives, but the characteristic habitats for species of this group are the small bodies of water, and the zones of vegetation in larger lakes. The third group, the canthocamptids (of the Harpacticoida) comprises copepods with bodies actually divided as in the cyclopids, but with scarcely any external evidence of the major divisions, with very short antennae, and with mouth parts adapted generally for seizing and for scraping; they can swim, but commonly they crawl or run on the bottom, raking up food among the decaying leaves and débris or in the

<sup>1</sup> Part of a study of copepods aided by a grant from the Rockefeller Fund for Research in Pure Science at the University of North Carolina.

foliage of aquatic or semiaquatic mosses; these crawlers and rakers inhabit, characteristically, the extreme littoral regions of ponds and the smallest pools, springs, runs, and bogs, and they even occur in damp wood or in moss that is not submerged.

The groups have been named in the generally assumed order of specialization as indicated by evidences from studies of morphology and of development. As regards geographic distribution of the species composing the several groups, we find a marked contrast between centropagids and cyclopids. The copepods of the more primitive group, the centropagids, seem to have shown great plasticity in recent geologic times, so that different geographic regions have each their particular assemblage of species. Those of the second group, the cyclopids, on the other hand, offer comparatively little evidence of recent specific differentiation. More concretely, it may be said that one is surprised to find in the eastern portion of the United States any species of centropagid that can not readily be distinguished from any found in Europe or even in the far western part of this country, but one would hardly be surprised to find anywhere in the United States a form corresponding as precisely as may be determinable to any species of the genus *Cyclops*, *s.lat.*, or its subdivisions. This does not mean that cyclopids are less variable in form than centropagids—in fact, the reverse seems to be true; but the same or extraordinarily similar patterns in diversity seem to repeat themselves precisely in localities widely removed from one another; “splitting” or “lumping” by systematists dealing with *Cyclops* is the reflection of diverse personal views not as to the significance of geographical types but rather as to the taxonomic value of particular structural patterns that may be noted in one place as well as in another; for many species of cyclopids (not all) it now appears that the same materials of variation present themselves in most widely remote regions. Parenthetically, it seems noteworthy that the one group of copepods for which resting eggs are chiefly known, eggs that, it would seem, might readily be widely distributed by winds, is the very group whose species are generally most narrowly limited in distribution; while, on the other hand, the one group, cyclopids, in which resting eggs are unknown<sup>2</sup> comprises many species of characteristically broad and, in some cases, world-wide distribution.

How is it with the copepods of the most specialized of fresh-water

<sup>2</sup> Advanced resting stages are indicated for species of cyclopids, while resting eggs are known for one or two species of harpacticoid copepods, and advanced resting stages for others.

families, the one with which we are immediately concerned? We do not yet have a proper basis of information. For long this group was almost totally neglected outside of Germany and Norway. Perhaps the great majority of species have been described within the past two or three decades, and few of these from America, and the known species have been little studied from the standpoint of variation. Very shortly we shall refer more particularly to the American species and their possible relations to species known from Europe.

The general neglect of Harpacticoida by the great majority of American collectors and students of fresh-water copepods is undoubtedly due chiefly to the unusual difficulties of identification. It is not only that harpacticoids are relatively small, usually opaque, and, as collected, frequently obscured by mucus and debris; but the integument has such light-refracting qualities that, even after painstaking dissection, some of the diagnostic characters are not always plainly evident. A further difficulty, and a particularly serious one in this case, arises from the fact that a good many of the descriptions of native species are fragmentary and unaccompanied by adequate illustrations, which are almost indispensable for the proper determination of harpacticoids. It is a major purpose of the present paper to provide such descriptions, illustrations, and diagnoses of some species as will facilitate identifications, form a better basis for the study of specific variations, and, perhaps, lead also to the discovery of new species. We have treated the species for which we have been able to obtain adequate material. Records of other species for which our material is limited or wanting are given in the table, page 83.

#### METHODS OF COLLECTING AND PRESERVING

Although harpacticoid copepods are extraordinarily widespread in occurrence, and frequently very abundant, they are not ordinarily taken in collections of the Microcrustacea; one is more likely to find them in collections made for the purpose of securing Protozoa or oligochaetes. It is appropriate, therefore, to offer some suggestions as to methods of collecting. Selecting habitats where there is comparatively little water and a good deal of cover, as small springs, the runs below them, marshes, or the shores of small ponds, the collector may employ a spoon to dip the bottom sand and sediment, scraping among the leaves or vegetation, pour each spoonful into a small handnet of fine bolting silk, India linen, or unbleached muslin, and finally wash the contents of the net into a bottle of water; or, large quantities of the bottom scrapings may be taken

up in a pail, the contents of the pail stirred violently, and, after the heavier material has settled, the water is poured through the net. In some cases we have obtained good collections by gathering moss from the rocks *above the water* in a small spring run, and washing this violently in a finger bowl of water. In the laboratory, the collected material is put into finger bowls and allowed to settle until the water becomes clear. If the copepods are plentiful, they may frequently be seen by the eye as they crawl or occasionally swim, from place to place; where they are less common, it is necessary to take up a small quantity of the surface sediment with a pipette, place it in a watch glass or petri dish, and examine it under a low-power binocular microscope. It is desirable to make the examination the same day that the material is brought in, for harpacticoid copepods generally are so sensitive to high temperatures and to light that many of them will not survive under laboratory conditions for more than a day.

For assurance in identification, females with eggs sacs should be sought. Mating pairs are next best, and they are easily found as they travel coupled in tandem for hours or days; the males in such a couple are mature, but the females may be either sexually mature (sometimes with egg sacs) or in the last stage before maturity. If the female is in the last stage preceding maturity, the abdomen will be 4-segmented, the first two segments (the fifth and sixth body segments) of ordinary length, and the last segment, representing the fourth and fifth, of the abdomen, rather longer than the segment preceding it; if the female is mature, the abdomen will also be 4-segmented, but the first two segments will be partly or entirely fused to form the long genital segment, and the last segment, representing the fifth, now separated from the fourth, relatively short. Such diagnostic characters as are presented by the first and second antennae, first foot, furca, and margins of the body segments can often be observed in the whole animal, but, except on the foundation of a considerable degree of experience, identification is impracticable without dissection under the binocular with very sharp needles to obtain views of each of the swimming feet and the fifth feet.

A simple technique of preservation that has proved very satisfactory to the author is as follows: Drop the copepod when first taken into a dish of clear water to get rid of incidental sediment; then take it up with the pipette and drop it with as little water as possible into a square watch glass of 95 per cent alcohol (or into a spoon of water heated to boiling over the burner, or into a watch glass of hot sublimate solution);

after half an hour in 95 per cent, run down through 80 per cent alcohol to 70 per cent (or, if hot water or sublimate solution was employed for killing, run up through alcohols, with the usual procedures for removing sublimate); transfer from 70 per cent alcohol to strong cochineal solution, prepared several days in advance (concentrated solution in 70 per cent alcohol, 10 mg per 100 ml of alcohol, shaken several times during three days, and finally filtered and kept in paper-wrapped bottle or in the dark). Leave in the stain overnight, then transfer through 70 per cent and 80 per cent alcohols, five minutes in each, to 95 per cent alcohol in a square watch glass one-third filled with alcohol; pour carefully into this watch glass enough of a 50/50 to 2/3 mixture of glycerine and 95 per cent alcohol to fill the container; leave the dish uncovered (but protected from dust) to permit gradual evaporation of the alcohol.

Cochineal does not readily overstain the copepods but will leach out in the subsequently used alcohols, if the material is allowed to remain in them too long. The stain seems to be permanent in glycerine, and copepods may be left in the last dish indefinitely; by the following day, however, the alcohol should be largely lost, and the animals can easily be transferred with the point of a needle to a very small drop of pure glycerine on a slide for examination or dissection. One or two additional transfers to drops of glycerine and warming on the flame may be necessary to remove all alcohol and water. The use of a desiccator is convenient, where covering can be deferred for a day.

If permanent mounts of parts are to be prepared, as is commonly desirable, prepare several slides with one or two minute drops of pure glycerine in each. As a part is removed, transfer it on the needle point to one of the droplets; surround each droplet with four small squares of paper of appropriate thickness, and then carefully place a circular cover-glass so that the glycerine forms a small circle under the center of the cover; place a small lump of hard paraffin (63°) by the side of the cover and hold the slide over a burner just long enough to permit the paraffin to melt and run under the cover. In course of time the cover is likely to separate from the paraffin, allowing air or moisture to enter; this is prevented by sealing with a ring of thick balsam. The preparation is best studied before the balsam is added, since, if the object does not lie just right, the paraffin can be melted again by passing the slide over a burner and the object caused to roll by tapping on the cover. This method is adapted from Birge (Ward and Whipple, 1918, p. 688). •



## TAXONOMY

Certainly the problems of the student of canthocamptid copepods have been greatly simplified by the recent contributions of P. A. Chappuis, of Rumania, who has reviewed the fresh-water harpacticoids of the world and, incidentally, has described several species from America. Of most importance to the general student of this group are his "Tableaux Dichotomiques" (1928), "Revision du Genre *Canthocamptus* Westwood" (1929a), and "Die Unterfamilie der Canthocamptinae" (1929c). In the two last-mentioned and most important papers, Chappuis has revived two or three old genera and set up new ones within the limits of the older genera *Canthocamptus* of Westwood and *Moraria* of Scott (*Ophiocamptus* of Mrázek). In all, 11 genera are proposed for the subfamily Canthocamptinae, with a number of subgenera. If, with this group of copepods, the genera can not be very precisely or briefly defined, the difficulty may lie partly with the material and not entirely with the systematist. Nevertheless, I am not able to distinguish in any positive way between the genera *Bryocamptus* and *Echinocamptus* as defined by Chappuis. The two diagnoses are strikingly parallel; only two parts seem to offer possible distinction: (1) The endopodite of the first foot seems to be more highly developed in *Echinocamptus*; it is described as 3-jointed in *Echinocamptus* and 2- or 3-jointed in *Bryocamptus*, longer than the exopodite in the former, and as long as or shorter than the exopodite in *Bryocamptus* (but it is actually somewhat longer than the exopodite in *B. zschokkei*); (2) the endopodite of P<sub>2</sub> of the male has the same peculiarities in the two groups, but is said to be "asymmetrisch" in *Bryocamptus*, with reference, presumably, to the taper toward the tip (right and left endopodites are alike). The uncertainty of these distinctions leads us to treat the two proposed genera as one—*Bryocamptus*. While we are not sure that species of *Bryocamptus* can always be distinguished from those of the restricted genus *Canthocamptus*, we are provisionally distinguishing *Canthocamptus*, *Bryocamptus*, and *Attheyella*,<sup>3</sup> mainly following Chappuis, as follows:

*Canthocamptus* Westwood, 1836 (characters emended, chiefly after

<sup>3</sup> Gurney's monograph (1932) has appeared since this report was submitted for publication. He does not recognize Chappuis's subfamily Canthocamptinae (for freshwater harpacticoids) nor most of his genera except as subgenera. Following Gurney, the species listed in this paper under the genus *Bryocamptus* would remain in the genus *Canthocamptus*.

Chappuis):<sup>4</sup> Rostrum small; posterior margins of body segments weakly dentate (or smooth?); accessory branch of second antenna 2-jointed; endopodite of  $P_1$  (first foot) highly modified, 3-jointed, exceeding exopodite by length of distal segment or more (agreeing in this respect with *Attheyella*); those of  $P_2$  and  $P_3$  of female 3-jointed, longer than first two segments of exopodite; that of  $P_2$  of male 2-jointed; copulatory process of second segment of endopodite of male relatively short, the process itself being about as long as the whole ramus. (Animals relatively large.) Type species: *Monoculus staphylinus* Jurine.

*Bryocamptus* Chappuis, 1929a (including also *Echinocamptus* Chappuis, 1929a—characters from Chappuis, with slight modification): Rostrum small; posterior margins of body segments smooth or very inconspicuously dentate; accessory branch of second antenna 2-jointed; endopodite of  $P_1$  shorter than exopodite or exceeding it but slightly; endopodites of  $P_1$ ,  $P_2$ , and  $P_3$  2- or 3-jointed, that of  $P_2$  of male regularly 2-jointed; copulatory process of second segment of endopodite of  $P_1$  of male much longer than the whole ramus. (Animals small.) Type species: *Canthocamptus minutus* Claus.

*Attheyella* Brady, 1880 (characters emended after Chappuis, and including *Elaphoidella* Chappuis, 1929a): Rostrum very prominent; posterior margins of body segments generally obviously toothed; accessory branch of second antenna 1-jointed; endopodites of  $P_1$ ,  $P_2$ , and  $P_3$  2- or 3-jointed, but commonly 2-jointed in female; copulatory process of second segment of  $P_3$  of male variable, but generally long. (Animals of diverse sizes.) Type species: *Canthocamptus crassus* Sars.

These genera are all alike in having the first antenna 7- or 8-jointed (7-jointed in some species of *Bryocamptus* and *Attheyella*); exopodites of  $P_1$  to  $P_4$  3-jointed; endopodite of  $P_2$  of male 2-jointed; that of  $P_3$  of male 3-jointed; exopodites of  $P_2$  to  $P_4$  with setae on inner border and spines on outer border of two last segments of exopodite;  $P_5$  2-jointed; and many other common characters. It will be seen that positive distinctions between the genera are very few if any. The genera do, however, seem to represent natural groups, but I am inclined to feel that it would be better to regard *Bryocamptus* as a subgenus of *Canthocamptus*, as *Elaphoidella* is treated herein (following Gurney) as a subgenus of *Attheyella*. As Chappuis (1929a) defines the genus *Elaphoidella*, it is virtually identical with *Attheyella*, except that each furcal ramus has a marked

<sup>4</sup> Westwood's genus *Canthocamptus*, originally very broad and vague, has been progressively narrowed. However, *staphylinus* was the original type species.

dorsal crest ending in a toothlike process and the mesial expansion of  $P_1\sigma$  is without setae. The dorsal crest in question is no more prominent or distinctive than the remarkable lateral process of *Attheyella wierzejskii* Mrázek (see p. 123 below) or than the several peculiarities of the furca of *A. idahoensis* and *A. carolinensis*. Unless, therefore, we are to provide new genera for each of these species, which seems unnecessary, the need for *Elaphoidella* is doubtful.

I have not had occasion to consider critically the other genera of the subfamily, and my comments concerning the genera treated are made with full recognition of Chappuis's contributions toward clarification of the very complex situation offered by the Canthocamptinae. I would also acknowledge the courtesy of Chappuis in examining and commenting helpfully upon material submitted to him.

#### NORTH AMERICAN CANTHOCAMPTINAE

Table 1 lists the species and subspecies reported from North America. It may be noted that 10 of the recorded American forms are assigned to European species or subspecies, 6 being assigned to the species (or subspecies in case of *bidens coronata*) in the narrowest sense, and 4 distinguished as American subspecies, as follows:

*minutus* Claus and *minutus minnesotensis* Herrick

*pygmaeus* Sars

*zschokkei frigida* Willey and *zschokkei alleganiensis* Coker (possibly identical?)

*northumbricus* Brady (?) and *northumbricus americana* Herrick

*bidens coronata* Sars

*musciicola* Richters

*wierzejskii* Mrázek

There remain 16 distinctively American species, and 4 of these are represented also by subspecies, as follows:

*staphylinoides* Pearse and *staphylinoides sinuus* Coker

*newyorkensis* Chappuis

*hutchinsoni* Kiefer

*minusculus* Willey

*subarcticus* Willey

*australis* Coker

*hiemalis* Pearse, *hiemalis nivalis* Willey, and *hiemalis brevifurca* Coker

*morrisoni* Chappuis and *morrisoni elegans* Chappuis

*illinoisensis* Forbes

*pilosa* Chappuis

*carolinensis* Coker

*bicolor* Wilson

TABLE 1  
CANTHOCAMPTINAE OF NORTH AMERICA<sup>1</sup>

SPECIES REPORTED <sup>2</sup>	LOCALITIES	PROBABLE NEAREST EUROPEAN RELATIVE
[ <i>C. (Canthocamptus) staphylinus</i> (Jurine, 1820)]. <sup>3</sup> <i>staphylinoides</i> Pearse, 1905.	Illinois (Coker, herein); Massachusetts (Pearse, 1906, Wilson, 1932); Montana (new record); <sup>3</sup> Montreal (Willey, 1925); Nebraska (Brewer, 1898; Pearse, 1905); Vancouver Island (Chappuis, 1929c); Wisconsin (Coker, herein); Connecticut (Kiefer, 1931). See p. 92.	<i>staphylinus</i> (Jurine).
[ <i>assimilis</i> Kiefer, 1931]. <i>staphylinus sinuus</i> , new sub-species.	North Carolina (Coker, herein). Connecticut and New Jersey (Kiefer, 1931)? See p. 92.	Do.
<i>C. (Bryocamptus) minutus</i> Claus, 1863.	Minnesota (Herrick, 1884); Massachusetts (Pearse, 1906, Wilson, 1932).	<i>minutus</i> Claus.

<sup>1</sup> In addition to the species included in the subfamily treated in this paper, there are a number of harpacticoid copepods that live more or less indifferently in fresh or brackish water: *Marshallia albuquerquensis* Herrick and *M. brevicaudata* Herrick, described from New Mexico (Herrick, 1895), and the former reported also from Massachusetts (Wilson, 1932); *Viquierella paludosa* Mrázek, reported by Chappuis (1927) from West Orange, N. J.; and the following, at least, from the region of Woods Hole, Mass.—*Harpacticus gracilis* Claus, *Nitocra spinipes* Boeck, *Laophonte talipes* Wilson, *Laophonte proxima* G. O. Sars, *Stenocaris minor* (T. Scott), *Parastlenocaris brevipex* Kessler, *Metis jousseaumei* (Richard)—the last mentioned found in water with a mere trace of salt (Wilson, 1932.) Wilson reports *Tachidius brevicornis* Lilljeborg only from salt water but mentions that it is known to live in England in pools of pure rain water. None of these are known to occur far away from salt water.

<sup>2</sup> Practically all the species, except those of the genus *Moraria*, described or reported from North America were given the generic name *Canthocamptus*, which is used in this table (indicated by the letter "C.") in the old broad sense. The names of species presumed to have been reported by error, of those now reduced to synonymy, and of those now unidentifiable are inclosed in brackets, with appropriate footnote references. Montana records are all based on specimens sent me by Prof. R. T. Young.

<sup>3</sup> Listed by Marsh (1918) but without explicit statement of its occurrence in America.

TABLE 1—Continued

SPECIES REPORTED <sup>a</sup>	LOCALITIES	PROBABLE NEAREST EUROPEAN RELATIVE
<i>minutus minnesotensis</i> Herrick, 1884.	Minnesota (Herrick, 1884) <sup>4</sup> ; New York (Chappuis, 1927); Montana (new record).	Do.
[ <i>minutus occidentalis</i> Herrick, 1879]. <sup>5</sup>		
<i>newyorkensis</i> Chappuis, 1927.	New York (Chappuis, 1927).	Do.
<i>hutchinsoni</i> Kiefer, 1929b.	Connecticut (Kiefer, 1929b).	<i>minutus</i> Claus or <i>vej-dofskyi</i> Mrázek.
<i>minusculus</i> Willey, 1925.	New York and Quebec (Willey, 1925).	<i>vej-dofskyi</i> Mrázek.
<i>pygmaeus</i> Sars, 1863.	New York (Chappuis, 1927).	<i>pygmaeus</i> Sars.
<i>subarcticus</i> Willey, 1925.	Quebec (Willey, 1925).	<i>pygmaeus</i> Sars or <i>arcticus</i> Lilljeborg.
<i>zschokkei frigida</i> (Willey, 1925).	Do.	<i>zschokkei</i> Schmeil.
<i>zschokkei alleganiensis</i> , new subspecies.	New York and North Carolina (Coker, herein).	Do.
<i>australis</i> , new species.	North Carolina (Coker, herein).	Do.
<i>C. (Echinocamptus) hiemalis</i> Pearse, 1905.	Montana (Coker, herein); Nebraska (Pearse, 1905).	?
<i>hiemalis brevifurca</i> , new subspecies.	New York and North Carolina (Coker, herein).	?
<i>hiemalis nivalis</i> (Willey, 1925).	Quebec (Willey, 1925).	?
<i>morrisoni</i> Chappuis, 1929b.	Indiana (Chappuis, 1929b).	<i>praegeri</i> Scourfield or <i>dacicus</i> Chappuis?
<i>morrisoni elegans</i> Chappuis, 1929b.	Kentucky (Chappuis, 1929b).	Do.
<i>C. (Attheyella) northumbri-cus</i> Brady, 1880. <sup>6</sup>	Florida (Marsh, 1926) (?).	<i>northumbri-cus</i> Brady

<sup>4</sup> *C. minnesotensis*, described as a new species by Herrick (1884), was reduced to subspecific rank by Chappuis (1927).

<sup>5</sup> The subspecies *minutus occidentalis* Herrick (1879) was later reduced by the original author to the synonymy of *minutus*.

<sup>6</sup> Herrick included *northumbri-cus* in his lists of 1884 and 1895 but was not explicit as to its occurrence in America; it is not always possible to tell from Herrick's reports whether the species mentioned are American. Regarding some he gives home localities; regarding others he says "not found in America;" while concerning others, as *northumbri-cus*, he is noncommittal. Marsh (1918) carries this species over into his list and also records it from Florida (1926).

TABLE 1—Continued

SPECIES REPORTED <sup>1</sup>	LOCALITIES	PROBABLE NEAREST EUROPEAN RELATIVE
<i>northumbricus americanus</i> Herrick, 1884.	Massachusetts (Pearse, 1906); Minnesota (Herrick, 1884); North Carolina (Coker, herein); Quebec (Willey, 1925); <sup>7</sup> Connecticut (Kiefer, 1931); Wisconsin (Coker, herein).	Do.
[ <i>northumbricoides</i> Willey, 1925]. <sup>7</sup>		
[ <i>willeyi</i> Kiefer, 1925]. <sup>7</sup>		
<i>illinoisensis</i> (Forbes, 1876).	Illinois (Forbes, 1876); Massachusetts (Pearse, 1906); Minnesota (Herrick, 1884); Nebraska (Pearse, 1905); New York (Chappuis, 1927); New York and North Carolina (Coker, herein); Quebec (Willey, 1925). <sup>8</sup>	<i>crassus</i> Sars or <i>northumbricus</i> Brady?
[ <i>hyperboreus</i> Willey, 1929]. <sup>8</sup>	.	
<i>pilosa</i> Chappuis, 1929b.	Indiana and Kentucky (Chappuis, 1929b).	?
<i>carolinensis</i> Chappuis, 1932.	North Carolina (Chappuis, 1932, and Coker, herein).	?
<i>bicolor</i> Wilson, 1932.	Massachusetts (Wilson, 1932).	?
<i>wierzejskii</i> Mrázek 1893.	New York (Coker, herein).	
<i>idahoensis</i> Marsh, 1903.	Idaho (Marsh, 1903); Montana (Coker, herein).	?
<i>bidens coronata</i> (Sars, 1904). <sup>9</sup>	North Carolina (Coker, 1926 and herein); Pennsylvania (Coker, herein).	<i>bidens</i> Schmeil subspecies <i>coronata</i> Sars.

<sup>7</sup> Willey described specimens from Quebec under the name *northumbricoides*; this name being preëmpted, Kiefer substituted *willeyi*, which Chappuis has properly reduced to the synonymy of *northumbricus americana*. See page 110.

<sup>8</sup> Willey's species *hyperboreus*, previously reduced by Chappuis to the rank of subspecies, is herein assigned to the synonymy of *illinoisensis*. See page 116.

<sup>9</sup> My species *caroliniana* has been reduced by Chappuis to the synonymy of *bidens* Schmeil subspecies *coronata* Sars. See page 130.

TABLE 1—*Concluded*

SPECIES REPORTED <sup>2</sup>	LOCALITIES	PROBABLE NEAREST EUROPEAN RELATIVE
[ <i>caroliniana</i> Coker, 1926]. <sup>9</sup> [ <i>tenuicaudis</i> Herrick, 1884]. <sup>10</sup> [ <i>cavernarum</i> Packard, 1888]. <sup>10</sup> <i>Moraria laurentica</i> Willey, 1927.	Quebec (Willey, 1927).	<i>schmeili</i> van Douwe or <i>duthiei</i> Scott or <i>similis</i> Lilljeborg. Do.
<i>laurentica americana</i> Chappuis, 1927. <sup>11</sup> <i>affinis</i> Chappuis, 1927.	New Jersey (Chappuis, 1927). New York (Chappuis, 1927).	Do. Do.
<i>cristata</i> Chappuis, 1929b. <i>Epactophanes muscicola</i> Richters, 1900.	Indiana (Chappuis, 1929b). New York (Chappuis, 1927). <sup>12</sup>	<i>poppei</i> Mrázek. <i>muscicola</i> Richters.

<sup>10</sup> Herrick's *tenuicaudis*, described doubtfully from "hasty sketches" and fragmentary notes, is naturally unidentifiable; it may have been a form of *staphylinus*, but no one can say. Packard's *cavernarum*, from Mammoth Cave, Ky., seems also unidentifiable.

<sup>11</sup> Described as a new species by Chappuis (1927) but later reduced by him (1931) to the rank of a subspecies of *laurentica*.

<sup>12</sup> First reported by Chappuis (1927) as *Epactophanes richardi muscicola* Richters but later listed by the same author (1929c) as shown.

*idahoensis* Marsh

*laurentica* Willey and *laurentica americana* Chappuis

*affinis* Chappuis

*cristata* Chappuis

In this summary we disregard six names now reduced to synonymy: *assimilis* Kiefer, *minutus occidentalis* Herrick, *northumbricoides* Willey and its substitute *willeji* Kiefer, *hyperboreus* Willey, and *caroliniana* Coker, and two named species that are presumed to be unidentifiable for inadequacy of description: *tenuicaudis* Herrick and *cavernarum* Packard.

Further studies may be expected to bring substantial changes in this list. It must be apparent from the record that knowledge of distribution of harpacticoid copepods in North America is extremely limited; we have hardly any knowledge of them except from a very few regions, while there are scattering records from a dozen other localities. The records may be classified geographically as shown in Table 2. Appar-

ently most of the records are based on chance collections or on material taken incidentally, although the material is widely distributed, and, where special search has been made, fairly plentiful.

Owing to the inadequacy of the records, the distribution of species need not be discussed in detail, but the following general comments on the fauna and its distribution by groups is appropriate:

The group of *staphylinus* (Jurine), represented by *staphylinoides* Pearse and its subspecies *sinuus* Coker, is general in distribution—North Carolina to Montreal and Vancouver Island.

The group of *minutus* Claus, most numerous, has been presumed to be almost exclusively northern in distribution. In this group are included *minutus* Claus, *minutus minnesotensis* Herrick, *newyorkensis* Chappuis,

TABLE 2  
GEOGRAPHIC CLASSIFICATION OF SPECIES OF CANTHOCAMPTINAE

EAST	NUMBER OF SPECIES RECORDED	CENTRAL	NUMBER OF SPECIES RECORDED	WEST	NUMBER OF SPECIES RECORDED
New York.....	10	Minnesota.....	4	Montana.....	4
North Carolina....	8	Indiana.....	3	British Columbia	
Quebec.....	8	Nebraska.....	3	(Vancouver Is-	
Massachusetts.....	5	Illinois.....	2	land).....	1
Connecticut.....	1	Kentucky.....	2	Idaho.....	1
Florida.....	1	Wisconsin.....	2		
New Jersey.....	1				
Pennsylvania.....	1				

*minusculus* Willey, *hutchinsoni* Kiefer, *pygmaeus* Sars, *subarcticus* Willey, *zschokkei frigida* Willey, *zschokkei alleganiensis* Coker and *australis* Coker—ten species and subspecies in all, reported variously from New York, Connecticut, Massachusetts, Minnesota, and Quebec, and now two species (*zschokkei alleganiensis* and *australis*) from North Carolina.

The group of *echinatus* Mrázek, represented by two species and three subspecies (*hiemalis* Pearse, *hiemalis nivalis* Willey, *hiemalis brevifurca* Coker, *morrisoni* Chappuis, and *morrisoni elegans* Chappuis) comprises species reported from various parts of central and eastern North America—Nebraska, Indiana, North Carolina, New York, and Quebec. •

The group of *northumbricus* Brady includes only three American species, two of which, *northumbricus americana* Herrick and *illinoisensis*



Forbes, are probably the commonest and most widely distributed of all North American harpacticoids, being found everywhere in central and eastern regions, from Minnesota and Quebec to Florida. The third, *pilosa* Chappuis, is yet known only from Kentucky. (Wilson's *bicolor* from Massachusetts may belong in this group.)

Species of *Moraria* are seemingly northern in distribution, being reported only from Indiana, New Jersey, New York, and Quebec.

There remain a few species to be considered singly: *A. bidens coronata* Sars, of world-wide but sporadic occurrence, is recorded in America only from North Carolina and Pennsylvania; *A. carolinensis* Chappuis is now known only from North Carolina; *A. idahoensis* Marsh only from the Northwest (Idaho and Montana); and *Epactophanes muscicola* Richters only from New York.

#### DESCRIPTIONS OF CERTAIN SPECIES

(For diagnosis of Genera, see pp. 80, 81)

#### *Canthocamptus staphylinoides* Pearse *sinuus* n. subsp.<sup>5</sup>

*Canthocamptus staphylinoides* Kiefer, 1931?

Plate 1; Plate 2, figs. 1-6

This is one of the larger harpacticoids, relatively slim of body with slender antennae and with the abdomen proportionately short, about seven-tenths of cephalothorax in length and but little narrower. The furca is long, slender, and delicately tapering, with sinuous interior margin. The anal opercle has a small number of broad spines, which may be very thin and quite inconspicuous in spite of their size.

*Body of female.* Moderately slender and gently tapering toward posterior end, with slight constriction in middle; cephalic segment almost as long as the four succeeding segments of cephalothorax combined;

<sup>5</sup> The criterion for the category subspecies, as employed in this study, may be stated as follows: The possession of characters none of which seem to be notably beyond the range of variation of the type, but which nevertheless serve in combination to give a distinctive pattern to specimens from a particular region. In the case of *sinuus*, we may have been overconservative in designating the form as a subspecies, since we do not know that the spines on the inner margins of the furca are within the range of variation of *staphylinoides*; but experience with other copepods indicates such a degree of variability in the development of small spines on the furca that we are inclined to depreciate the significance of this character, at least until it may be determined that *staphylinoides* in the type locality is invariable in the possession of these spines.

rostrum projecting as a blunt triangular process between bases of antennae; posterior margins of thoracic segments smooth; posterior division of body shorter than anterior, the segments sharply marked off from one another; genital segment somewhat shorter than two succeeding ones combined; genital and two succeeding segments each bearing a subterminal ring of fine spines, the rings interrupted dorsally on genital and following segment, completed on next to last segment by finer spines in mid-dorsal region; posterior margin of segments produced into fine, sawlike teeth, sometimes very difficult to observe; last segment shortest; stout marginal spines on ventral side of last segment (pl. 1, fig. 3). All segments of the body, except the first, with 4 or 5 transverse rows of fine spinules.

*Anal plate.* Inconspicuous and fringed with a row of 6 to 8 rather stout spines, about 6 in female and about 7 in male.

*Caudal furca.* Longer than anal segment, more than three times as long as broad, tapering slightly; inner margin distinctly sinuous, incurved at about midway of length; the inner of the two well-developed apical setae about three-quarters the length of the animal, and not "jointed"; the outer about one-third the length of the inner, "jointed" near the base, and strongly barbed; innermost seta very delicate, hair-like, lying close at base of stoutest seta, but curving inward near the tip.

*Appendages of head.* Anterior antennae rather slender and graceful, longer than cephalic segment, and armed with many setae; proximal segments much broader than terminal, but all relatively narrow. Posterior antennae 3-jointed, rather stout, middle segment bearing 2 widely separated setae on anterior edge; distal joint slightly shorter than proximal; accessory ramus generally 2-jointed, indistinctly so if at all in some examples, less than half as long as basal joint of inner, and bearing 4 short setae, 1 on first segment and 3 on distal segment, 2 being terminal and 1 halfway of outer margin.

*Swimming feet.* First leg with outer ramus a little longer than first joint of inner ramus, basal joint stouter than two succeeding joints; last joint with a single spinule about middle of inner side; inner ramus slender and almost twice as long as outer; terminal joint of inner ramus bearing at tip a single long geniculate seta, a slender finely denticulated spine more than half as long as the seta, and subterminally a hairlike seta about one-third length of terminal seta.

Second, third, and fourth legs: All slender; second and third with both rami 3-jointed; inner ramus of second extending to middle of third segment of outer ramus; inner ramus of third leg about as long as first two

segments of outer ramus. Inner ramus of fourth foot 2-jointed, about as long as first segment of outer ramus; spination as shown in Plate 1, Figure 9.

Fifth foot: Distal joint oblong in shape, bearing on outer edge 2 short and subequal spines, and a somewhat longer subterminal spine, and at tip a conspicuously longer and stouter spine, just inward of which is a very short but strong spine; inner margin of joint fringed with fine hairs; inner expansion of proximal joint bluntly rounded and extending about one-third length of distal joint, bearing 5 strong marginal spines, the outer spine the shortest, and the next one the longest, extending about to end of apical spine of distal joint; between the bases of these two a very short barbed spine; the next two about equal in length, a little shorter than the second, and about twice as long as the outermost spine; the small outward expansion of proximal joint bearing a long, slender seta and, near its base, about 2 strong, toothlike spines.

*Ovisac.* Elongate-ovate. *Spermatophore:* Elongate-oblong and attached to genital opening by a very long, slender, and frequently coiled pedicel. (Pl. 1, fig. 5.)

*Males.* Somewhat smaller than females; the fringe of spinules near posterior margin of each segment of abdomen not extending completely around the body of the animal, but interrupted across a portion of the dorsal part of each segment, the gaps being in some cases filled in with minute spinules. First pair of legs of about the same structure as in female. Inner rami of natatory legs noticeably modified; that of second leg slender and 2-jointed, the last joint having on its outer margin a peculiar notch, representing the vestige of a joint. (The segment as a whole is as figured by Schmeil for *staphylinus*, but it has a much more regular margin, and a spine in lieu of a hooked process on the inner margin, with other differences.) Inner ramus of third leg strongly modified, the first joint very short and the second elongate and produced into a process about twice the length of the segment; the third joint shorter, slender, ovate, and tipped with 1 long and 1 short bristlelike seta. Inner ramus of fourth leg produced at end on outer side into a rather blunt process, about two-thirds as long as the segment, with 2 rather long setae at apex of segment, and 2 shorter setae on inner margin, one just below the other.

"The basal segment of the male fifth foot is armed with one long and one short spine, both ciliated; two small bristles on the inner margin and two on the process which bears the long spine on the other side. The second joint is armed with six spines, all of which are plumose,

except the second from the inside, which is small and naked [barbed in Chapel Hill specimens]. The third spine from the inside is longest and the inner one, which is attached at the proximal third of the segment, has longer and more delicate cilia than the others.

"The genital plate is armed with three spines. The inner one is ciliated and the longest of the three. The middle one is shorter than the outer one" (Pearse, 1905).

*Length.* Male, 0.71 mm; female, 0.95 mm.

*Color.*—Reddish yellow.

*Holotype* (female).—U. S. N. M., No. 66347.

*Habitat and distribution.* Found in a small bayou connected with Bolins Creek below Strowd's Meadow; in Glen Burnie Marsh; in pools near Perch Hole, Chapel Hill, N. C., December 1, 1927, and again in February, 1928, females with eggs being taken both times; and at other places. This is one of the commonest harpacticoids at Chapel Hill.

The species was described by Pearse (1905) from Nebraska, with the statement that it is "the most common harpactid in eastern Nebraska"; later (1906) he reported it as abundant in Massachusetts. We have found a single specimen on a slide of harpacticids collected by Prof. S. A. Forbes in pools near Normal, Ill., in 1882. Chappuis records the species from Vancouver Island, and I have specimens from Flathead Lake, Mont., and Lake Winagra, Wis. Willey (1925) reports it from the region of Montreal, Canada. Kiefer's records from Connecticut and New Jersey are discussed below. Probably the species, with varieties, is widely distributed.

*Distinguishing characters.* The long furca with sinuous inner margin (var. *sinuus*); the comparatively smooth and little-tapered body; the slender antennae; the 6 (about) broad but thin spines on anal plate; the segments of swimming feet of females: 3/3, 3/3, 3/3, 2/3; of males: 3/3, 2/3, 3/3, 2/3.

*Systematic position.* Pearse expressed doubt as to whether the form taken in Nebraska should be regarded as a distinct species or as a variety of *staphylinus* (Jurine) but resolved the doubt in favor of the former alternative. His decision seems to be entirely correct. Incidentally he remarks that this is the copepod reported by Brewer (1898) as *minutus*.

This copepod, as found in Chapel Hill, N. C., is quite similar in general appearance to *Canthocamptus staphylinus*, as described and illustrated by Schmeil (1893b) and again by Sars (1911), but it differs from that species in the following main points: Furca more elongate and

slender and very similar in form to that figured by Lilljeborg for *glacialis*; the inconspicuous anal plate armed with 6 or 7 strong spines instead of with many weaker spines; the longer cephalic and shorter genital segments; ovisac more elongated; spermatophore much shorter; distal joint of fifth foot of male very much shorter; outer spine of mesial expansion of proximal joint of that foot much shorter and inner spine much longer than in *staphylinus*. Furthermore, the distal joint of the endopodite of the second foot of the male shows decided differences as previously mentioned, and the corresponding segment of the fourth foot, while having the same general peculiarities of form, has two more well-developed setae.

The question arises as to whether our forms should be referred to Pearse's species. Pearse's description is brief, but it appears that his

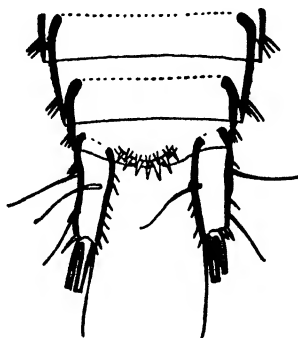


FIG. 1. *C. staphylinoides* Pearse. Last abdominal segments and furca of specimen from Flathead Lake, Mont.

specimens and ours conform closely in almost every point of distinction from *staphylinus*. We note but two significant differences. One is in the form of the furca: Pearse's figures indicate a straight inner margin instead of a sinuous one as in our specimens; he also refers to small spines on the inner margin of the furca, which are wanting in all ours, but which we find well developed on examples from Montana. Provisionally, therefore, we give our form a distinctive name *sinuus* (referring to the common form of the inner margins of the furca) with sub-specific rank.

Kiefer (1931), with material from the vicinity of New Haven, Conn., and Cape May County Farm, N. J., found two closely related copepods, one of which he identifies with Pearse's *staphylinoides*, which he re-describes, and the other of which he makes a new species, *C. assimilis*.

The form that he describes as *assimilis* is virtually identical with *staphylinoides*, s. str., as evidenced by comparison of his description with that of Pearse or with specimens that I have from the geographic vicinity of the type locality of *staphylinoides*. The form that he describes for *staphylinoides* is essentially identical with the subspecies *sinuus* described above. See Table I, p. 83.

We have a male example from Flathead Lake, Mont. (from Prof. R. T. Young) in which the furca has approximately straight inner contours, with a series of prominent spinules. The specimen has the peculiarity of having two series of spines on the oval operculum, one above the other (text fig. 1). The subterminal rings of spines of abdominal segments show wide gaps in the dorsal side. Otherwise the specimen conforms almost perfectly with the description. This I should take to be a good representative of Pearse's species—but for the double series of spines on the anal operculum, which may be an abnormality. Examples from Lake Winagra, Wis., found in material sent me by Prof. Chancey Juday, conform with Pearse's description, being different from *sinuus*.

This is the only species from North America that would remain in the genus *Canthocamptus* as restricted by Chappuis.

***Bryocamptus zschokkei* (Schmeil) *alleganiensis* n. subsp.**

Plate 4

Copepods collected in wet moss in Allegany State Park, N. Y., show in most respects remarkable conformity with Schmeil's description of *Canthocamptus zschokkei* Schmeil (1893a, 1893b), but differ in some details to a significant degree. They are best described by comparison with Schmeil's description.

*Armature of body.* The back and sides of the anterior part of the body are smooth, except for sense hairs, although some specimens show on or near the body an abundance of minute rodlike bodies, the nature of which is undetermined; they may be foreign materials or hardened secretions. The extremely fine denticulations of the posterior margins of abdominal segments mentioned by Schmeil, have been seen only on the ventral side of males. This is the first instance to be cited of a distinct point of difference accompanied by a suggestion of close relationship. Again, the very fine spinules at the fusion line of the first and second segments of females of *zschokei* are not seen, but in males a short series of strong subterminal spines is found on each side of the first segment.

The strong subterminal series of spinules is found on the sides of the second segment in both sexes, but the continuation of these series dorsally in males and ventrally in females is not seen; the series is not completed ventrally in either sex. The third segment of females has the lateral series continued by fine spinules a short way ventrally, but not all the way, there being a distinct median ventral gap, although in males the series is unbroken ventrally. The lateral series of the fourth segment is completed ventrally, in the females by very fine spinules, in the male by spinules somewhat smaller than those of the sides. Schmeil does not mention a sexual distinction here, except in respect of *a few large median ventral* spines in the female, but these are not found in our specimens. The last segment has the three or four strong lateral spinules in both sexes, and the strong ventral spinules described for the male of *zschokkei*.

*Anal plate.* The very large strong teeth in small number constitute a characteristic feature; Schmeil records 5 to 7 for females, 3 to 6 for males; we find 3 to 5 for females, 3 or 4 for males; Donner (1928) reports 2 to 7 for specimens of *zschokkei*, presumably from the region of Leipzig.

*Furca.* The furca differs clearly in form from the figures given by Schmeil, each branch being decidedly bent in a horizontal plane. That of the female is distinctly larger than that of the male. On the sides are two setae, each with a neighboring spinule, the more posterior and lower being the longer. The usual single dorsal seta and the vestigial inner terminal seta are present; the chief terminal seta is about twice as long as the outer, and both have very sparse barbs; in the male, as in *frigida*, the dorsal seta is situated at the end of a short crest near the base of the large inner terminal seta. Near the inner distal angle of each ramus of the furca is a short half circlet of 5 or 6 spinules, extending from near the base of the large terminal seta around to near the base of the outer terminal seta below. Except possibly as regards this series of spinules and the dorsal crest of males, the armature of the furca seems to correspond precisely with that of *zschokkei*.

*Appendages of head.* The 8-jointed first antennae with comparatively short spines, the second antennae with 2-jointed accessory branch, and the 2-jointed mandibular palp are all as described by Schmeil, unless the sense clubs of the antennae are less stout. The other mouth parts present nothing of note.

*Swimming feet.* The outer branches of all are 3-segmented and the inner 2-segmented, except, of course, the third of the male.

First feet: inner branches alike in males and females, scarcely exceed-

ing the outer; setae of inner border of second segment of endopodite are slenderer than shown by Schmeil. The long seta on inner border of second segment of exopodite is quite naked except for a few long barbs near the base; Schmeil remarks that in spite of the apparent insignificance of this detail it merits mention because of its constancy as a character of this seta and of the corresponding setae of the following appendages, and the remark is equally applicable to our specimens.

Second feet: The inner branch is short, slightly overreaching the second segment of the outer, and differing in males and females, the males lacking the small terminal spine at outer apical angle, but showing, in some examples at least, a distinct notch on the outer border near the apex. Like Schmeil's, our examples have only two inner border setae on second segment, but they differ from his form in not having the peculiarly crossed setae on inner side of the first segment in the female (an abnormality in his specimen?). The distal segment in the male tapers to a very narrow tip.

Third foot: The endopodite is not just like that of the second, as Schmeil says, but has three instead of two setae on the inner border; the outer branch is like that of the fourth, as mentioned by Schmeil. Chapuis (1931) says that *zschokkei* in Europe is variable in this respect. The endopodite of the third foot of the male is 3-jointed as usual, the first segment having a small seta on the inner side, the second segment having a long slightly curved process, more than twice as long as the last segment of the endopodite and showing one or two very minute barbs near the tip (these not mentioned by Schmeil). The third segment is narrowed toward the distal end where it bears a short and very slender curved seta and a long broad and somewhat flattened club, possibly sensory, that tapers suddenly to a slender curved tip. I have not seen anything like this in any other species. It is quite different from the long slender tapering unbarbed seta of Schmeil's description and figure.

Fourth foot: This is as described by Schmeil and with the same differences in the sexes: The endopodite is very short, reaching only to the middle of the second segment of the exopodite. The male lacks the seta of the first segment of the endopodite and one of the inner border setae of the second segment of this branch.

Fifth foot: In the female the median expansion of the first segment has 6 spines; if these are numbered beginning from the outside and arranged in order of length, beginning with the longest, the order of lengths is 5, 6, 3, 4, 2, 1. According to Schmeil's (1893b) description of *zschokkei*, 3 is the longest, and the relative lengths, as shown in his



Plate 4, Figure 18, are 3, 5, 6, 4, 2, 1. That is the only difference noted. The second segment has 2 setae on the outer border, with small spines above the first, a slender terminal seta flexed outward, a long unbarbed terminal seta, and a short spine at the inner distal angle, all agreeing very well with *zschokkei*. In the male the mesial expansion has 2 spines of about equal length; the second segment has 2 setae on the inner border, a slender terminal hair, a short terminal spine, and 2 setae on the outer border where Schmeil indicates but one; Schmeil also shows the mesial expansion as more regular in outline than is ours.

*Spermatophore*. The long-ovoidal form corresponds well with Schmeil's figure.

*Length*. Females, 0.49 to 0.54 mm; males 0.36 mm. They are among the very smallest of copepods, our examples being smaller than the sizes indicated by Schmeil (females, 0.6 mm, males 0.45 mm).

*Holotype* (female).—U. S. N. M. No. 66348.

*Habitat and distribution*. Our first examples were taken along with *hiemalis* in collections of silt from a small spring run in Allegany State Park, N. Y., just north of the Allegany School of Natural History. Since only a very occasional single specimen was found, it was presumed that their occurrence in the silt was accidental, and search was made for other possible habitats. The remaining examples from this locality were found by washing the damp moss that grew in abundance on some of the *exposed* rocks; the moss was evidently their chief habitat in this run. From the data assembled by Donner (1928), it appears that *zschokkei* in Europe is found only in cool, running water (springs, brooks, shores of lakes). The habitat of our specimen conforms to those conditions. *B. zschokkei* is regarded as stenothermal and as a "glacial relict" species. The fact that our specimens from New York were found a dozen miles beyond the boundary of the area of glaciation would be of no significance, but we also found it abundantly in damp moss overhanging a run below a spring in a ravine north of Tenney Circle, Chapel Hill, N. C., May 18, 1932; this is far removed from any area of glaciation. *B. zschokkei*, with its several subspecies, seems to be generally distributed in Palearctic regions (Chappuis).

*Distinguishing characters*. The short compact body with short rounded furca, the few and very prominent spines on anal plate; the short first feet with 2-jointed endopodite about equal to exopodite; fifth foot with high mesial expansion and short second joint.

*Systematic position*. These specimens correspond so closely with the

description and figures of Schmeil's *zschokkei* that without the most minute examination they would readily be assigned to that species; furthermore, there are points of striking similarity in minute details, as in the armature of the furca, the unusually sparse barbing of the terminal furcal setae, and the peculiar barbing of the setae of the inner border of the second segments of the exopodites of the second to fourth swimming feet. On the other hand, there are small but distinct differences in the spinulation of the segments of the abdomen; the furca are distinct in form. In the fifth feet of the female there are differences of relative lengths of setae on the mesial expansion; but the chief difference is in the male, where there is an additional seta on the inner border of the second segment—in the armature of that segment where constancy is generally to be expected. Another notable point of difference is in the peculiar broadened terminal club of the endopodite of the third foot of the male.

The species falls within Chappuis's genus *Bryocamptus*, and the subgenus *Bryocamptus*, *s. str.*: *Bryocamptus* (*Bryocamptus*) *zschokkei alleghaniensis*.

On the basis of Chappuis's diagnosis of subspecies of *zschokkei*, ours differs from Chappuis's *orientalis* and Minkiewicz's *tatricus* in being without the dorsal spines on the fifth segment of the body. This negative character it shares with Chappuis's *himalayensis* and with Schmeil's *zschokkei*, *s. str.* It differs from the former in having five instead of six setae on the second segment of  $P_5$  of the female, and from *zschokkei*, *s. str.*, in having six instead of five setae on the same segment of  $P_5$  of the male, as well as in a number of other characters previously noted. Our specimens conform with Willey's *frigida* in the spination of the third foot of the female and in that of the second segment of the fifth foot of the female. From Willey's Figure 21, it appears that his *Attheyella frigida* does not possess the peculiar club (?) on the tip of the endopodite of the third foot of the male. We can not compare our form with Willey's in all respects, and it is possible that ours should be identified with his, which should be given subspecific rank, as Chappuis (1931) has already recognized. We can not follow Willey in identifying Schmeil's *zschokkei* with Rehberg's *fontinalis*. The name *alleghaniensis* is here used to identify the form that we describe in detail. (One female found in the type locality since this paper went to press has six setae on the second segment of the fifth foot.)

**Bryocamptus australis n. sp.**

## Plate 5

Closely related to *zschokkei* and notable for its occurrence at a relatively low latitude.

*Form and armature of body.* Body small and compact, but not robust; back and sides of anterior part of body smooth, except for a few scattered and very inconspicuous hairs; posterior margins of segments of anterior and posterior portions of body entire; no spinules on last thoracic segment; submarginal transverse series of spinules on back of first abdominal segment of male, and similar series at corresponding place on genital segment of female—in this respect like *zschokkei* but unlike *zschokkei alleganiensis*; similar series on back and sides of second segment of males and genital segment of females; submarginal series of spinules on third and fourth segments completed ventrally (not interrupted as in *alleganiensis*), the ventral spinules being only slightly smaller; these series sometimes interrupted dorsally by a wide gap on fourth segment and by a smaller gap on third; last segment with lateral spinules and some larger ventral spinules, a small gap between ventral and lateral series.

*Anal plate.* Posterior margin rounded and bearing 4 to 8 large spinules.

*Furca.* Alike in males and females, very short; inner margin somewhat distorted dorsally; 2 slender lateral setae with short stout spines near their bases and the usual dorsal seta; 3 terminal setae, the inner very small and inconspicuous (not always observed) and the outer well developed, about half as long as the middle, which is about two-thirds length of body; a subterminal transverse series of flaring spinules on ventral side and extending up on inner side. Furca as a whole much like that of *alleganiensis*, except that the terminal setae are not sparsely barbed as in that subspecies and in *zschokkei*, s. str.

*Appendages of head.* First antenna 8-jointed, slender, hardly as long as first segment of body; the sensory club on fourth joint not extending to tip of antenna. Second antenna with 3 terminal spines and only 2 bent ("prehensile") setae; the longest of the terminal spines with 2 or 3 strong barbs near the middle, corresponding in this respect to the usual bent setae, except that the barbs are exceptionally stout (pl. 5, fig. 3); accessory branch 2-jointed, its proximal segment with one seta and distal segment with 3, one of the latter having the form of a *fairly strong spine*. (This is one of the notable characters of this species.) Mandible as shown in Plate 5, Figure 4, the palp being like that of

*alleganiensis*, but the seta stouter and more spinelike; joint separating proximal and distal segments of palp not very distinct, if always present; fourth segment of antenna of male not much enlarged.

*Swimming feet.* First foot with *both rami 3-jointed*, but otherwise much like that of *zschokkei*, the endopodite sometimes slenderer than shown in Plate 5, Figure 5; first segment of endopodite without seta at inner apical angle. Second foot much like that of *alleganiensis*, but with terminal segment of exopodite not relatively so long; proximal segment of endopodite without seta at inner distal angle; distal segment of endopodite with 2 rather short inner border setae (or only one, sometimes), 2 long terminal setae, one very long (it may be twice as long as the member), and a subterminal outer border spine; second segment of outer ramus with long slender seta at inner distal angle, this seta, and the corresponding one in third and fourth foot, usually showing the 2 or 3 long lateral "barbs," characteristic of *zschokkei* and *alleganiensis* (but they are inconspicuous in this form and may easily be overlooked); third segment with 1 inner border seta, 2 long terminal setae, and 3 outer border spines, one of which is subterminal. Third foot much like second but with following differences: Tip of outer ramus has an additional long seta; proximal segment of inner ramus has a seta at inner apical angle; distal segment of inner ramus, as in the second foot, may have 1 or 2 inner border setae, but it is more likely than the second to have 2—*asymmetry* may prevail, there being 1 inner border seta here in one foot and 2 in the other foot of the pair. There seems to be a tendency to have one less inner border seta on this segment in *australis* than in *alleganiensis*, which has 2 on distal segment of second endopodite and 3 on that of the third.

Endopodite of second foot of male has the peculiar form of that of *zschokkei*, with greatly reduced tip bearing 2 setae, one of which is very small, with 2 inner border setae, and with a distinct notch on the outer border, this notch being notably farther from the tip than in *zschokkei* and *alleganiensis*. Third foot of male very like that of *alleganiensis*, except that at the tip of the distal segment of the endopodite there are 2 plumose setae, instead of a seta and a club (*zschokkei*, according to Schmeil, has 2 terminal setae, but the longer one is not plumose); process from second segment of endopodite has a distinct barb near the tip (pl. 5, fig. 9).

Fourth foot of female with outer ramus like that of third; inner ramus much like that of third, but with only one inner border seta and with different relative lengths of terminal setae—practically identical with

that of *alleganiensis*. Endopodite of fourth foot of male not greatly different from that of female, but somewhat smaller and with achaetous proximal segment—very like that of *alleganiensis*.

Fifth foot: Mesial expansion in female fairly high, but not reaching end of distal segment, and having only 5 marginal setae, with a small gap between second and third as if a seta were missing (the gap is found in all examples observed); relative lengths of setae, as numbered in order beginning from the outside—5, 4, 2 (or 2, 4), 3, 1—(pl. 5, fig. 12) differing from *alleganiensis* (pl. 4, fig. 14) and from *zschokkei* as figured by Schmeil. (*B. zschokkei* and *B. z. alleganiensis* differ from *B. australis* also in having 6 marginal seta on this segment.) Distal segment in female with 5 setae—one inner border (subterminal), 2 terminal, and 2 outer border (one of these subterminal); the middle seta slender, hairlike; the long terminal seta distinctly plumose, not naked, as in *zschokkei* and *alleganiensis*. Fifth foot of male with mesial expansion little developed and bearing 2 stout spines of unequal length, the inner the shorter; distal segment small, with 5 setae—one inner border, 2 terminal and 2 outer border, besides 1 or 2 very small spines. As in *zschokkei*, there is one less inner border seta on this segment than in *alleganiensis*, but the missing seta is indicated in one example (pl. 5, fig. 13) by a small spinule.

*Length.* Females, 0.49–0.55 mm.; male, 0.41–0.51 mm.; about the same size as *alleganiensis*.

*Holotype* (Male).—U. S. N. M., No. 66349.

*Habitat.* Taken from sphagnum moss and weed in swamp along shore of White Lake in Bladen County, N. C.

*Distinguishing characters.* Those of *alleganiensis*, except, most notably, for the 3-jointed inner ramus of the first foot.

*Systematic position.* This copepod is evidently very closely related to *zschokkei* Schmeil, which it resembles in general form, in the prominent anal spines, in the form of the furca, and in such details as the possession of transverse series of spinules on the middle of the genital segment, the peculiar stiff lateral hairs on basal parts of inner border setae of the middle segments of the outer branches of the second to fourth feet, although these hairs are not so easily seen as in *zschokkei*, and in the conspicuous notch on the inner border of the endopodite of the second foot of the male, the notch having, however, a distinctly less distal position in our copepods. It differs from *zschokkei* in such details as the normal barbing of the apical furcal setae, instead of a notably sparse barbing, but more particularly in the spinelike form of one of the terminal setae of the accessory ramus of the second antenna and in the 3-

jointed inner ramus of the first foot. These characteristics, supplemented by various minor points of distinction, are sufficient basis for the establishment of a species.

*Bryocamptus australis* is of special interest for its occurrence as far south as White Lake, which is at about latitude 34°, 38', N., on the coastal plain, 50 miles from the ocean and but little above sealevel. Nearly all the closely related species, if not all, are reported only from northern or alpine regions: *zschokkei* itself has, indeed, been termed a "glacial relict."

***Bryocamptus hiemalis* (Pearse) *brevifurca* n. subsp.**

Plate 2, figs. 7-9; Plate 3

This small species is recognized by its relatively smooth integument, the approximate equality of anterior and posterior portions of the body, the very short furca, widely separated and divergent, the moderately eccentric position of the terminal setae, and the flaring whorllike grouping of spines on the furca near the distal end, these being more readily observable in dorsal view. Other characteristic features are the fine erect hairs on all segments seen in side view, the apparent "fourth" terminal seta, short antennae, and the endopodite of first foot, which is not greatly longer than the exopodite. The reduced mesial expansion of the fifth foot of the male is also distinctive.

*Form and armature of body.* Cephalothorax hardly deeper than the abdomen, the first segment about equal to the following three; rostrum rather prominent and broadly triangular; terga smooth except for prominent erect sensory hairs. Abdomen about equal to anterior portion of body; a few very delicate erect hairs on dorsa of all segments, two or more to a segment, these most evident on males; a pair of plumose setae near genital openings. First two segments of the abdomen of female incompletely fused, appearing in side view as two distinct segments. The last thoracic and the several abdominal segments not markedly unequal, except that the last two abdominal segments are somewhat shorter than the others. Margins of all segments entire, but with submarginal annuli of spinules on all abdominal segments, the series being complete in females only on the two segments following the genital segment, the spines smaller on dorsal and ventral sides and sometimes with a gap on dorsal side; that on the posterior part of the genital segment interrupted ventrally, and that at the place on the genital segment representing the posterior margin of the first segment restricted to the lateral regions of

the dorsal side. A short row of spinules very similar to the one last mentioned found about midway of the dorsal surface of the last thoracic segment. Males with annuli of spinules completed dorsally and ventrally by small spines on the second, third and fourth abdominal segments, the series being found only on the dorsal side of the first segment.

*Anal plate.* Generally with finely spinulose margin. I have two females from Allegany State Park, N. Y.; one has very fine spinules on anal plate, the other very long and strong spinules; they are otherwise identical.

*Furca.* Very short, commonly wider than long, far removed from each other and divergent, the caudal setae arising somewhat eccentrically from the outer part of the distal end; two well-developed terminal setae as usual, the inner about twice as long as the outer; innermost terminal seta small and hairlike; an apparent *fourth* terminal or sub-terminal hairlike seta at the outer distal angle, representing a lateral seta of extreme distal position; two setae on dorsal surface about half-way of length of furca, one near inner margin, and one near outer margin or on upper part of exterior side—this and the “fourth terminal” represent the two lateral setae of some other species. A notable feature of the furca is the fan of strong spinules near the distal extremity.

*Antennae.* First antennae of females 8-segmented but short and rather stout, otherwise not unusual. Second antennae 3-jointed, with a slender 2-jointed accessory branch (“exopodite”).

*Swimming feet.* First foot of females with exopodite and endopodite 3-jointed; endopodite not extremely modified, the exopodite being about equal to first two segments of the endopodite; slender, curved, hairlike setae found at inner terminal margin of second and third segments of the endopodite, that on the second segment very hairy.

Second, third, and fourth feet: *Female*—Endopodites 2-jointed, the basal joint very short, especially in the third and fourth; the distal segment with 2 setae on inner margin, but the proximal often small and indistinct or lacking on the second foot; 2 long terminal setae and a spine at outer terminal angle. Spines and spinules strongly developed on all the appendages, the spines on outer side of exopodite being notably long, as described by Douwe for *hoferi*. *Male*—Endopodite of second foot much like that of the female, but it may lack the terminal spine found in the female. Endopodite of third foot 3-jointed, as usual, the long, curved process of the short second segment rather stout and not evidently barbed; the third segment with a long hair and a short plumose seta at the end. Endopodite of fourth foot relatively little

developed; proximal segment without a seta; one of the inner border setae of second segment lacking and one of the terminal setae very short.

Fifth foot: Mesial expansion of fifth foot of the female very high and with 6 stout spines, the third from the outside being much the longest. The corresponding part of the male with but 2 spines, the inner being the longer. The suboval second segment of the appendage in the female with 2 short spines on outer margin and 1 on inner, and with 2 terminal setae, the inner being the longer; the last mentioned seta often notably long and strong. The corresponding segment in the male broad and angular, bearing on outer margin 3 strong spines, on inner margin a weaker but longer spine; a very short spine near the tip, and a long strong terminal spine.

*Length.* Females, 0.63, 0.77 mm; males, 0.51, 0.58 mm; one mating pair: Female, 0.77 mm, male 0.5 mm.

*Holotype* (male).—U. S. N. M. No. 66350.

*Habitat and distribution.* Collected near Chapel Hill, N. C., in Snail Run, May, 1926; in Glen Burnie Marsh, March 2, 1929; and in a spring in Battle Park, where a very little water was filled with leaves and debris; also taken in the tow in upper end of the lake at Allegany School in Cattaraugus County, N. Y., July, 1929. The species was described from Nebraska, and I have specimens from Montana; it is represented in Quebec by the subspecies *nivalis* (Willey).

*Distinguishing characters.* As given in first paragraph.

*Systematic position.* The species would appear to be closely related to Douwe's *hoferi*, described from a single specimen taken in the Bodensee; the form and armature of the furca and the armature of the last abdominal segment are distinctive. When compared with Pearse's description of *hiemalis* from Nebraska (Pearse, 1905), our form differs in the following particulars, at least: The anal operculum, unarmed in *hiemalis*, is spinulose either finely or strongly; the furcal rami are about as long as broad ( $1\frac{1}{2}$  times as long as broad in *hiemalis*); the endopodite of the fourth foot of the female (pl. 3, fig. 7) has a spine on the basal segment, and the middle terminal seta is extremely reduced (as in *nivalis*). The mesial expansion and the second segment of the fifth foot of the male are not so short as shown by Pearse, although not always so long as shown in our Plate 3, Figure 5. Pearse does not mention the presence of dorsal hairs on the body, except on the anal operculum. The question arises whether our form is not specifically distinct.

Pearse's types can not be located, but we have specimens from Flat-



head Lake, Mont., received from Prof. R. T. Young, which are very instructive. Examples of both sexes correspond very closely with Pearse's description and figures, except as regards the fourth foot of females. Of two females taken at the same station on the same date, one has the fourth foot with endopodite of the reduced form displayed

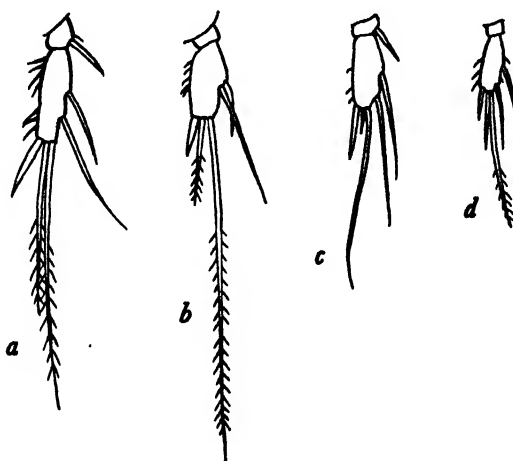


FIG. 2. Endopodites of fourth feet of female.

(a) Specimen of *hiemalis* from Flathead Lake, Mont., remarkable in that the member is virtually identical with typical endopodite of *third* foot (cf. Pl. 3, fig. 3a)—and with endopodite of its own third foot.

(b) Type of *hiemalis* from Nebraska (after Pearse), marked by absence of seta on proximal segment, reduction of middle terminal seta and crowding of the two inner border setae.

(c) Specimen from Quebec, *nivalis* (after Willey), much like (a) but for extreme reduction of middle terminal seta. (Cf. Pl. 3, fig. 7, for example from Chapel Hill.)

(d) Specimen from Flathead Lake, Mont., like (b) but for normal spacing of inner border setae; the member is much reduced in size as compared with that represented by (a), which is drawn to the same scale. (a) and (d) are from individuals taken in the same collection.

by our specimens and with no spine on the proximal segment, but with the middle terminal seta not notably reduced (text fig. 2 d); the other, bearing egg sacs, has the endopodite of that foot practically identical with that of the third foot (text fig. 2 a; compare pl. 3, fig. 3 a, third foot of local form). The agreement of each with Pearse's description is otherwise so close, even to the absence or inconspicuousness of hairs

on the terga, that I think we must conclude that the endopodite of the fourth foot of the female is variable. The extremes of diversity noted for this part might be described as: (a) *Unmodified* (i.e., closely resembling endopodite of the two preceding feet, the third foot especially); and (b) *reduced* (i.e., relatively small in size, the basal segment achaetous, the setae of the terminal segment reduced in size, the middle terminal seta especially) (fig. 2). The reduced form is typical, but specimens approximating both extremes may occur in the same collection. The endopodite of a male from Flathead Lake, Mont., (text fig. 3) corresponds closely with that of males from Chapel Hill (Plate 3, fig. 8).

It follows that Willey's specimens from Quebec could not properly form the basis of a new species differentiated, as they seem to be, only by the reduction of the endopodite of the fourth foot (Willey, 1925).



FIG. 3. Endopodite of fourth foot of male *hiemalis* from Flathead Lake, Mont.

It is true that the presence or absence of a spine on the basal segment of an endopodite has been held by the best taxonomists to be a specific distinction, but properly, we think, only when the presence or absence of the one seta is regularly associated with other features of distinction. Willey's specimens, as described, and ours too, are hardly more extreme as to the reduction of the endopodite in question than is one of the females from Flathead Lake, which occurred along with an example that was relatively far at the other extreme. Possibly his form *nivalis* should be ranked as a subspecies or variety and ours be assigned to it. We have not been able to examine Willey's specimens, and do not know whether they differ from *hiemalis* in other respects than those mentioned. Provisionally, we distinguish the form that we describe in detail as a subspecies, *brevifurca*, marked by the reduced endopodite of the fourth

foot of the females, with achaetous proximal segment, and extremely reduced middle terminal seta (agreeing with subspecies *nivalis* Willey in those respects), and also by the spinulose anal operculum, shorter furca, less reduced mesial expansion and distal segment of fifth feet, and stronger development of hairs on the terga. The fourth foot of the male seems to be the same in examples from all regions with minor variations among specimens from Chapel Hill (pl. 3, fig. 8) and among those from Montana (text fig. 3) as to relative lengths of setae and occurrence of minute spinules on the segments.

Our specimens from North Carolina and New York conform with Pearse's in size, his measurements being: Female, 0.77 mm; male, 0.55 mm. The Montana specimens conform with Willey's in size; Montana examples: Females, 0.56 mm; males, 0.41 mm; Willey's measurements: Females, 0.54 mm; males, 0.44 mm.

If we followed Chappuis, the name would be *Echinocamptus* (*Limnocamptus*) *hiemalis brevifurca*.

***Attheyella northumbrica* Brady *americana* (Herrick, 1884)**

*Attheyella northumbricoides* Willey, 1925.

*Attheyella willeyi*, nom. nov., Kiefer, 1929.

*Attheyella* (*Brehmiella*) *northumbrica* Brady *americana* (Herrick, 1884)  
Chappuis, 1930.

**Plate 6; Plate 7, figs. 3-5**

This is a short but very stout copepod with conspicuously large rostrum, very prominent buccal mass, and highly specialized first feet. The segments are so capable of telescoping one within the other that the animals present decidedly different aspects when extended and contracted. The anterior part of the body is broad and deep, the posterior part distinctly narrower, and tapering in depth so strongly that at the posterior end it is only about one-third the depth at base (pl. 7, fig. 5).

*Form and armature of body.* Animal with a characteristic contour when viewed from above; rostrum broad and deep, forming a prominent protrusion from the anterior margin; first segment about as long as the following four together and as broad as long. Next four segments successively narrower, so that between the first segment and the abdomen the contour curves distinctly inward to the last thoracic segment, which may be compared to a broad belt at the waist; abdomen broad but distinctly narrower than anterior part of body, and showing in dorsal

aspect a moderate taper to its posterior end; free margins of all thoracic segments of male, except the first, with some denticulation.

Abdominal segments and last two or three thoracic segments with finely denticate posterior margins, the dentations on last abdominal segment showing only on ventral side; abdominal segments with submarginal flaring fringes of spinules, incomplete dorsally; fine spinules in distinct pattern on sides of last thoracic segment. Lateral subterminal series of spinules on last four abdominal segments; a short series of such spinules on sides of first abdominal segment of male, but not represented in the female (such a series is described by Schmeil for *northumbricus*, female); lateral series on next to last segment connected ventrally by somewhat finer spinules; on the preceding segment the lateral series continued ventrally by fine spinules with a small break in mid-ventral region. Integument generally smooth.

*Anal plate.* With 12 to 18 slender, close-set spinules (pl. 6, fig. 8)—spinules somewhat smaller in my examples from Wisconsin, 20 to 24 in number.

*Furca.* Greatly reduced in size, narrowly articulated to body and set far apart but bent toward the middle line, so that the bases of the terminal setae are somewhat closer together than bases of the furca (pl. 6, fig. 8); two well-developed terminal setae, the inner very strong and about as long as the whole body, the outer much smaller and about one-third the length of the other; a dorsal seta and 2 delicate lateral setae, each accompanied by 1 to 3 spinules.

*Appendages of head.* Antennae of female long, slender, and moderately spinose; those of male markedly specialized, the fourth joint decidedly inflated. Antennule very small with 1-jointed accessory ramus bearing 3 well-developed setae. Mouth parts strongly developed, especially the maxillipeds, but not notably different from those of related species

*Swimming feet.* First feet with both rami 3-jointed and markedly prehensile, first segment of endopodite as long as or longer than entire exopodite (pl. 6, fig. 1—Schmeil's fig. 19 would apply almost as well).

Second, third, and fourth feet (except the third of males) with 3-jointed exopodite and 2-jointed endopodite. Spination of the second foot as shown in Plate 6, Figure 2, alike in males and females; the third of females (examples from Chapel Hill) differing from the second in having 2 setae on the inner margin of the terminal segment of the endopodite instead of 3 (3 setae here in examples from Wisconsin). Endopodite of fourth leg much reduced in size, the basal segment particularly

small; setae on inner margin well developed, 1 on first segment and 2 on second segment, besides 2 terminal setae and a spine.

Third foot of male relatively little specialized, second segment of endopodite a little longer than first segment and bearing a small spine and a series of hairs in addition to the process, which is about twice as long as the third segment and very slender at the tip; third segment slender and bearing at its tip a flexible hair about as long as the segment and a seta about twice the length of the segment; exopodite like that of female; the appendage as a whole notably less modified than that of *northumbrica* as figured by Schmeil; second segment not reduced in size and its process relatively short.

Fifth feet of female strongly developed and of a particularly graceful form; the mesial expansion of the basal segment bearing 6 plumose setae of only moderate length, supported on prominences of the margin of the segment; third seta from outside the longest, its length about equaling the width of the segment; seta at the outer angle borne on a marked prominence. A *conspicuous chitinized prominence* on the margin of this segment just mesial to the articulation of the second segment; between this prominence and the outer seta a short row of marginal spinules; second segment elongate-ovate in form, bearing a long and a short seta on the tip, another subterminal on the inner margin, and 2 short spines on the outer margin, near the end; its margins *and anterior face notably spinulose*.

Mesial expansion of each fifth foot of male with 2 or 3 short spines (not 4 as in *northumbrica*), the inner the longest; the prominence between the spines and the base of the distal segment very conspicuous; distal segment with 2 short spines on exterior margin, 2 terminal spines, the inner rather the longer, and an inner subterminal spine, besides spinules on outer and inner margins; anterior face of the segment not so notably spinulose as in female. In both sexes the fifth feet correspond very closely in most respects with those of *northumbrica*, but there are conspicuous differences, especially in the male.

*Color.* Our specimens were deep orange splotted with red, the eye a deep rose-red.

*Length.* Females, 0.56–0.73 mm; males, 0.54–0.69 mm.

*Habitat and distribution.* Found in shallow pools north of Bolins Creek at Glen Burnie, Chapel Hill, N. C., April 20, 1928. Subspecies described from Minnesota by Herrick and reported from Massachusetts by Pearse (1906); reported from Florida by Marsh (1926); examples

from Wisconsin found in material furnished me by Prof. Chancey Juday.

*Distinguishing characters.* The broad heavy body, stout rostrum, and extremely reduced furca; the spinulose face of second segment of the fifth feet; the fine spinules on the sides of the last thoracic segment; and the dentate margins of most of the segments.

*Systematic position.* As compared with Schmeil's description of Brady's *northumbricus*, our examples have the forepart of the body distinctly wider than the hind portion—not of about the same width—and they display a very heavy and conspicuous rostrum, not properly described as short and blunt. Instead of all segments being deeply toothed on posterior margins, the first two segments are scarcely if at all toothed. The integument, smooth or roughened by mucus, is not noticeably covered with fine spines, although series of spinules on the sides of the last thoracic segment are characteristic. The furca is shorter and its branches more oblique.

The 5 to 7 large spines, mentioned by Schmeil as being on each side of the genital segment at line of fusion, I have not found in females, although they are quite distinct at the corresponding place in males—just before the posterior boundary of the first abdominal segment. The wreath of spines on the third abdominal segment is completed below with spines of nearly ordinary size, instead of with spinules of another order of fineness.

The spines of the anal plate increase regularly in strength from the side to the mid-line; Schmeil shows them as irregular, but his description qualifies the characterization, as “oft recht ungleichmässig starker Dornen, welche von den Seiten nach der Mitte an Länge zunehmen.”

The outer spine of the second segment of endopodite of second foot of males is well developed, not lacking as in *northumbricus*; this character seems to be subject to variation in Willey's examples.

Herrick (1884) distinguished specimens from Minnesota under the varietal name *americana*. Schmeil (1893b), after comparison of his examples from Germany with the descriptions of Brady and of Herrick, and after his material had been examined by Brady, dismissed Herrick's variety; but Chappuis (1931), finding that Schmeil's German examples were different from both the British and the American, lets Herrick's name *americana* stand until proper comparison can be made with the British form.

Our specimens agree with Willey's *Attheyella northumbricoides* (1925)

in most of the rather minor points he gives as distinguishing *northumbrioides* from *northumbricus* as described by Schmeil. Our forms are perhaps a little larger than his (his measurements: Females, 0.6 mm; males, 0.45 mm), but we are not able to compare our specimens with his in most of the points of distinction we have emphasized, and Willey gives no figures. The name *northumbrioides* had previously been applied by Brehm to a species from China; Kiefer (1929a) substituted, therefore, the name *willeyi*, which Chappuis (1931) has reduced to the synonymy of Herrick's *americana*, as preferable for the present to ranking it with the British type species. I must concur in this judgment. The main distinction between Willey's form and the type is the preservation in the male of the outer apical spine of the second segment of the endopodite of the second foot, as to which the author remarks: "The two sides do not always correspond, but the normal condition is as stated."

The facts, that the chief distinguishing character of specimens from North Carolina (as compared with *northumbricus*) applies likewise to examples from Quebec, and that some variability is noted in the latter region, make it a reasonable assumption that we have to do with one form, north and south; to this it is appropriate for the present to apply Herrick's name.

By Chappuis's revision, this species falls in the genus *Attheyella*, subgenus *Brehmiella*.

***Attheyella illinoisensis* (Forbes, 1876)**

*Canthocamptus illinoisensis* Forbes, 1876

*Canthocamptus hyperboreus* Willey, 1925

**Plate 7, Figs. 1, 2; Plates 8, 9**

One of the larger species of fresh water harpacticoids of America is that collected and described by Forbes from pools near Normal, Ill. (Forbes, 1876) and later collected by Herrick in a peaty ditch near Minneapolis, Minn. (Herrick, 1895). It has been reported by Pearse from Nebraska and by Chappuis from New York, and these records will be discussed in a later paragraph. Illustrations did not appear with the original description, and those subsequently given by Herrick are of little use, but Pearse's figures of specimens from Nebraska are very good. By courtesy of the late Prof. Stephen A. Forbes, director of the State Natural History Survey of Illinois, and Dr. Theodore H. Frison, his successor, we have been permitted to examine the types, make dissections, and prepare for publication the accompanying illustrations made

from paratypes (pl. 7, figs. 1 and 2; pl. 8—except figs. 8 and 9). Since these drawings were made, we have taken the species from a marsh and various small waters near Chapel Hill, N. C. Text figures 4 to 6 and Plate 8, figs. 8 and 9, were made from local specimens. The figures of Plate 9 were made from examples from western North Carolina.

It has been found too that the male harpacticoids described and illustrated (but not named) in an earlier paper (1926) are virtually identical with males found at Chapel Hill paired with female *illinoisensis*. Those males were then recognized as specifically distinct from the females taken in the same collection and were provisionally assigned to the genus *Attheyella*, without attaching a specific name.

It is not necessary to repeat Forbes's full description. The following abbreviated description of females is based mainly on Forbes's original

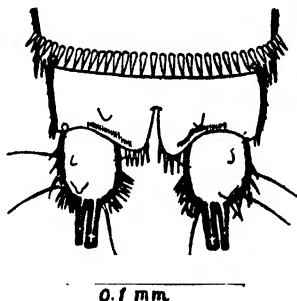


FIG. 4. *Attheyella illinoisensis* Forbes. Last abdominal segment and furca of specimen from Chapel Hill, N. C.—ventral aspect, female.

description, with some additions. The notations inclosed in brackets relate to observations made on examples from Chapel Hill, but not definitely confirmed for specimens from the type locality.

*Form and armature of body.* Body robust, shell smooth except for inconspicuous and incomplete circlets of spinules and denticles on abdominal segments and numerous parallel series of very inconspicuous spinules on the surface of the shell. First body segment (cephalic segment) nearly equaling the following four; posterior margin of last 2 or 3 thoracic segments usually dentate, but sometimes quite inconspicuously so. Abdomen about five-sixths, (0.82) [0.73–0.88] length of cephalothoracic region; first abdominal segments incompletely fused. Abdominal segments with posterior margin dentate especially on the sides and with a fringe of spinules near posterior margin on ventral half [which may be completed dorsally by very fine spinules].



*Anal plate.* Margined with fine spinules or with few small spines or bare.

*Furca.* Very short, as wide as long, subconic, not so long as last abdominal segment; with 2 terminal setae and a slender terminal hair; inner seta about as long as cephalothoracic region of body; outer seta about half as long as inner and with barbs only on outer side. Outer margin of furca with 2 setae, each accompanied by small spines; the dorsal seta supported on a distinct papilla; a comb of spines (3 to 6 or 8) extends obliquely from this papilla toward the rounded distal angle of interior margin [combs rather more pronounced in examples from Chapel Hill]; other spines on inner and terminal margins.

*Appendages of head.* Antennae slender, about as long as first segment of body, with 8 segments in female, 7 [8?] in male; antennule with very small 1-jointed outer ramus. Mouth parts with no notable peculiarities.

*Swimming feet.* First, second, and third feet with both rami 3-jointed [endopodite of second, at least, sometimes 2-jointed (text fig. 5)];<sup>6</sup> en-



FIG. 5. *A. illinoisensis* Forbes. Endopodite of second foot of female with the two distal segments incompletely separated. Example from Chapel Hill, N. C.

dopodite of first foot half again as long as exopodite, its first segment reaching about to end of exopodite; endopodites of second and third feet reaching only to middle of last segment of exopodites; inner ramus of fourth pair of legs less than half length of outer ramus, 2-jointed, with basal joint short, and terminal joint about as long as middle joint of outer ramus. Fifth foot in female with mesial expansion of basal segment reaching nearly to end of second segment [halfway at least] and bearing 6 plumose setae, of which the inner is the longest; outer segment elongate-ovate, truncate, with two terminal setae, 2 subterminal [one on each side], and one about midway of outer margin, and with spines on each margin, the outer terminal seta hairlike, as in the male.

<sup>6</sup> In collections from Chapel Hill we find females bearing egg sacs, and therefore mature, but having the endopodite variously 3-jointed, 2-jointed, or 2-jointed with outer segment partially divided (text fig. 5). Separation of genera on the basis of the number of segments in the endopodite of this appendage is clearly invalid.

The following description of the male is taken with slight revision from Coker (1926, pp. 254-255):

*Form and armature of Body* (male). Body distinctly rounded, tapering gradually from head to last abdominal segment, which is about one-half the greatest diameter of the body. Rostrum well-developed and triangular with acute anterior point (Coker, 1926, pl. 41, fig. 8). Setae and spines on appendages highly developed. Second to fifth abdominal segments each with a row of spinules near posterior ventral margin; a few spinules on sides of last thoracic and first abdominal segments. Last abdominal segment deeply notched, almost completely divided.

*Furca* (male). Length and width of branches approximately equal; each branch with 2 terminal setae and, just inward of the larger setae, a short slender curved hair about equal to length of the furca.

*Appendages of head* (male). Segmentation of the modified antenna difficult to make out with certainty, but apparently with 8 segments, the third and seventh very small; the sixth bearing a strong, hooklike spine. Posterior antenna with undivided basal portion and very small inner ramus; three of the terminal setae with the usual appearance of articulations in the middle of each. Mouth parts and antennae as illustrated in Coker (1926, pl. 41).

*Swimming feet* (male). Both branches of the first feet 3-jointed, the inner ramus very strongly developed with its basal segment as long as the entire outer ramus. Inner branches of the second and fourth feet 2-jointed, the basal joint being very small—less markedly so in the second. Third foot strongly modified, the third segment of inner ramus being elongate, truncate, and terminating in 2 long setae, and the second (middle) segment extended laterally by a strong process which is curved downward more than twice as long as the third segment and slender in its distal portion; this process is doubly barbed at the tip.<sup>7</sup> A feature of the spination of the appendages is the variable aspect of the barbs on the longer setae, which may be relatively close-set and straight, or sparser, long, slender, and flexible. Pl. 9, figs. 2-4 illustrate the several forms of barbs, and it may be noted that certain setae have short, close-set barbs on one side and slender, sparser barbs on the other, one of these being evidently intermediate in form between spine and seta.

Fifth pair of feet with basal segments confluent in middle line, the

<sup>7</sup> Two barbs (though much stronger) are shown by Delachaux (1918) at tip of corresponding process in *C. godeti*.

low, mesial expansion on each side bearing 3 strong but short spines and the external distal angle bearing a well-developed seta; second segment small and ovate, with 5 main spines, the second from within being much the strongest and the middle one slender and hairlike; also several small spines on inner and outer margins of this segment.

*Color.* Forbes gives the color as "light red." Our examples are gray.

*Length.* Females from Chapel Hill, 0.88 mm.; males 0.79 mm. Length given by Forbes, 1 mm. Length of male from Lake James, 0.64 mm. This specimen seems to have been shorter and stouter than mature males from Chapel Hill.

*Habitat and distribution.* Two males taken in plankton net, hauled near the surface in shallow water near the head of Catawba Lake division of Lake James, N. C., near the end of August, 1922; a single male taken, November, 1930, at Old Fort, N. C.; males and females not uncommon in the marsh at Glen Burnie, Chapel Hill, N. C., October, 1927, many being paired; late in December females carrying eggs (50 to 100 eggs to the sac) taken under the ice at this place by H. W. Dietz; also found in Snail Run, in the arboretum, and at various other places; one of the commonest of local harpacticoids, females with egg sacs and still in couple frequently found in January. A male found in a culture dish stocked from a wash south of the campus had furca with rami not noticeably asymmetrical and with 5 inconspicuous spinules on the anal plate. It was quite translucent and colorless except for brownish-yellow oil globules on each side of the alimentary tract. We have also taken females in subsurface plankton collections from a small artificial lake in Allegany State Park, Cattaraugus County, N. Y., and from a spring run nearby.

The species was described by Forbes from pools near Normal, Ill., and later reported by Herrick from a peaty ditch near Minneapolis, Minn. Pearse (1905) found the species on two different occasions among the filaments of *Vaucheria sessilis* in springs north of Florence, Neb., and (1906) records it as common in dredgings at Wellesley, Mass. Chapuis records it from a collection taken in moss from the park of Pelham Bay, N. Y. The copepods from Quebec described by Willey as *hyperboreus*, found in Quebec, are evidently of this species (see below).

*Attheyella illinoisensis* is apparently one of the most common and widely distributed harpacticoids in the United States.

*Distinguishing characters.* The robust and relatively smooth body, with very short furca; the segmentation of the appendages—females:  $\frac{3}{3}$ ,  $\frac{3}{3}$  or  $\frac{2}{3}$ ,  $\frac{3}{3}$ ,  $\frac{2}{3}$ ; males:  $\frac{3}{3}$ ,  $\frac{2}{3}$ ,  $\frac{3}{3}$ ,  $\frac{2}{3}$ ; the great development of the inner

ramus of the first foot; the strong modification of the third foot; the form of the fifth foot; and the form and spination of the furca, with a row of 3 or more spines on dorsal side, set obliquely and showing as a comb in side view.

*Systematic position.* Pearse's illustrations of the fifth feet of males and females would apply very closely to specimens from North Carolina, and those of the third foot and the terminal segments of the antennae of the males might be applicable or not; but his figure of the furca (plate 16, fig. 30) shows a plan of spination somewhat similar to that of typical *illinoisensis*, but different in form, and with the outer terminal seta bent at the base in a striking fashion, and quite unlike that observed in the types. We have observed a specimen with furca (text fig. 6) modified in the direction of the form depicted by Pearse, but not to such an

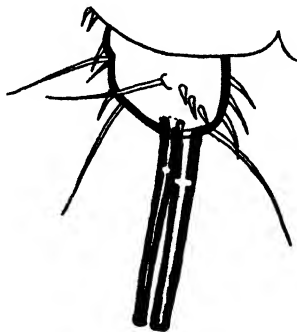


FIG. 6. *Attheyella illinoisensis* Forbes. Example from Chapel Hill, N. C. with terminal setae arising eccentrically—dorsal aspect, female.

extreme degree. The forms we show and the form he shows, however unlike in the extremes, may be presumed to be within the limits of variation of this species.

Chappuis's description and illustrations of specimens from New York are generally closely applicable to our specimens, with one significant exception. He shows the terminal segment of the exopodite of the fourth foot of the male with the subterminal outer spine and the terminal spine bent and crossed over each other in the fashion of scissors. We have seen a similar condition in a species of *Cyclops*, but do not find this in any male *illinoisensis* we have examined from Illinois, North Carolina, or western New York. The variability of harpacticoids is such that a specialization of this character unaccompanied by other differences is hardly to be accounted a specific distinction.

Willey (1925) described copepods from the Province of Quebec under the name of *hyperboreus*, distinguished from *illinoisensis* by having the endopodite of the second foot 2-jointed instead of 3-jointed, a distinction formerly regarded as of generic value. Chappuis (1931) gives *hyperboreus* subspecific rank. In his original description Willey says: "But for the very definite feature of the second foot in the female, my species would unquestionably be set down as being co-specific with *illinoisensis*." Since we find the number of segments in the endopodite in question to be, variably, 2 or 3, we place *hyperboreus* in the synonymy of *illinoisensis*. It may be recalled that in this species the female ordinarily has a 3-jointed and the male a 2-jointed endopodite of the second foot. We should be conservative, I think, in basing genera, species, or even subspecies on the possession by one sex of a secondary sexual character of the other.

The species is evidently widespread in distribution in the United States and Canada, although notable specializations in particular characters have been noted in Nebraska and in New York.

By Chappuis's revision, the species is assignable to the genus *Attheyella* (subgenus *Brehmiella*).

### ***Attheyella carolinensis* Chappuis, 1932**

#### **Plates 10, 11**

This is a small species with peculiarly armed furca and greatly reduced fifth feet of the male.

*Form and armature of body.* Body of female robust with slight but fairly uniform taper from cephalothorax to last abdominal segment; the rostrum very prominent, broad, and rounded anteriorly; the posterior margins of the shields of all segments sharply toothed, and the abdominal segments with series of flaring spines near posterior margins, ventrally and laterally. Genital segment of female incompletely divided. Males generally similar to females in form and sculpture but slenderer.

*Anal plate.* Margined with fine spines—30 or more. (Pl. 10, figs. 1, 9.)

*Furca.* Relatively long, the rami strongly divergent, flattened above and with sinuous contour in mature examples; rami less divergent in males, about equal in length to those of females. Chief apical seta in both sexes stout and about two-thirds length of body without furca; outer terminal seta little developed, short, slender, a little longer than furca; a very delicate hairlike seta at inner apical angle of furca of females (this was not observed in males and possibly is not constant in

females); two short lateral setae and one longer dorsal seta; furca flattened dorsally and bearing marginal rows of spinules; other spinules on sides in 1 or 2 vertical or longitudinal rows; arrangement of these spines difficult to make out but differing apparently in the two sexes (pl. 10, figs. 8, 9; pl. 11, figs. 12, 13); ventral contour showing a prominent angle at or near the end in fully grown examples (pl. 10, fig. 8; pl. 11, fig. 12), a little back from end in immature specimens (pl. 10, fig. 3).

*Appendages of head.* Antenna of female short, scarcely more than one-half length of first body segment, 7-jointed (sometimes 8?), the last segment slender and longer than the two preceding; fourth segment of male antenna much enlarged; sensory club on fourth segment in both sexes very long, passing end of antenna. Antennule having penultimate joint longer than distal, with two widely separated setae on outer margin; outer ramus 1-jointed, small and slender, with 2 lateral and 2 terminal setae of ordinary form. (Pl. 11, fig. 9, illustrates the antennule of a mating female—the outer ramus is slenderer in females carrying egg sac, but is still 1-segmented.) Maxilliped with strongly developed seta on the prominent apex of first segment, and with comb of spinules on outer side below articulation of second segment.

*Swimming feet.* First foot of female of strongly prehensile type; both rami 3-jointed, the slender inner ramus very long, twice as long as outer, its first segment longer than entire outer ramus. Second foot with inner ramus 2-jointed, and about one-half length of outer ramus; its first segment very small, with one seta; the second with 2 setae on inner border, 2 long terminal setae, and a small spine, the spine missing in males; outer ramus strongly spined, its 2 distal segments having each a seta on inner border, besides 2 terminal setae. Third foot like second, but longer, with longer spines, and with an additional long seta near end of each ramus on inner side. Fourth foot like third, but smaller and lacking the proximal seta found on inner margin of second segment of inner ramus of second and third feet.

Fifth feet with basal segment low, its mesial expansion with 4 setae—3 terminal or nearly so and the fourth on mesial margin; a short slender seta at outer apical angle; second segment elongate-oblong with 5 setae—2 terminal, 1 near end on mesial side, and 2 on outer side of which the proximal may be missing (pl. 11, fig. 4); none of the setae hairlike; spinules on anterior face of distal segment.

The appendages of an immature female, of which the first, second, third, and fifth are illustrated in Plate 11, Figures 5-8, agree in general plan and spination with those of the adult female, but are relatively shorter and broader.

First foot of male like that of female; second foot like that of the female, except that the endopodite lacks the short terminal spine. Third foot of male distinctly specialized (pl. 10, fig. 4), but the segments not extremely modified in form; process of second segment of inner ramus very long and slender, doubly curved but not evidently barbed at the finely tapered tip. Fifth foot with only one strong spine (or sometimes two) on mesial expansion of basal segment (pl. 10, fig. 7); outer segment like that of female, but the inner terminal seta stronger.

*Length.* Females, 0.7 mm; males, 0.58 mm.

*Habitat.*—Found among leaves and debris in outlet of small spring in Battle Park, Chapel Hill, N. C., on May 21, 1925 (none with eggs at that time), and again abundantly on February 8, 1930, when there were chiefly clasping pairs, and many of the females carried egg sacs, although still in clasp. A few clasping pairs taken from the same place on June 16, 1931. Found also in a small run below a spring south of the campus, May, 1926. In both places the trickle of water was scarcely evident for the accumulation of leaves. One example collected in a marsh at Glen Burnie on March 18, 1930. In a clasping pair the female is usually but not invariably in a submature stage.

*Distinctive characters.* Seven-segmented antennae; stout body of female; sculptured posterior margins of segments; prominent rostrum; strongly prehensile first feet; finely spinose anal plate; moderate modification of third foot of male; long furca and its spine pattern; and the strong middle terminal caudal seta, which is the only one well developed.

*Systematic position.* This copepod shows affinities with Chappuis's *putealis* and *elaphoides* of his genera *Elaphoidella*, but the reduction of the mesial expansion of the fifth feet of the male has not gone so far as in those species, there being a distinct expansion with 1 or 2 spines. I concur with Chappuis (1932) in placing this species within the limits of the genus *Attheyella* as redefined by him (1929a), although the furca of the male is not notably longer than that of the female and the endopodite of the second foot of the male differs but slightly from that of the female. It seemed to me possibly transitional between *Attheyella* and *Elaphoidella*.

***Attheyella wierzejskii* (Mrázek)**

*Canthocamptus wierzejskii* Mrázek, 1893

• Plates 12 and 13

A small harpacticoid with furca of bizarre form, found in the Allegany mountains of Western New York, is extremely near to, if not identical

with Mrázek's *wierzejskii*, a species that has been reported but rarely and only from Central Europe. I am indebted to Dr. J. Roy for aid in this identification.

*Form and armature of body.* Body small and rather slender, of relatively uniform width, the last abdominal segment very little narrower than broadest part of body. Posterior margins of all segments, except last, strongly dentate on back and sides and, in abdomen, below also. All segments except the first with several transverse series of fine spinules. Second (posterior part of genital segment), third and fourth abdominal segments in both sexes with lateral subterminal series of spinules, these series complete ventrally only on fourth (next to last) segments, completed dorsally on none. Last abdominal segment without subterminal spines except for 6 or 7 on each side ventrally.

*Anal plate.* Smooth or finely ciliate.

*Furca.* Differing in the sexes and of very remarkable form in the female, resembling that of *crassus* Sars in that the rami are broadest near the middle and narrow at each extremity, but departing from that species in several bizarre features, most conspicuous of which is the long, strong pointed process arising from inner margin near base of each ramus and extending posteriorly somewhat parallel with axis of ramus, this process about half as long as ramus and ciliate with long hairs; a strong blunt process on outer side of each ramus just beyond middle of length of ramus; a prominent curved dorsal ridge extending from base of ramus to place of origin of dorsal seta, about halfway of length of ramus (much as in *crassus*). Laterally, 2 setae and several shorter spinules, all proximal to the lateral process. Terminal setae very much as in *crassus*, the apical setae of the two rami strongly divergent; middle seta strongly swollen at base, its ciliation very fine, close, inconspicuous and apparently restricted to a short region; outer seta (in female) hardly one-fourth as long as middle seta, which it partly overlies, and lacking the marked elbow-bend near base that is characteristic of *crassus*; inner terminal seta very short, and distinctly thickened in proximal portion.

Furca of male not so strongly modified, each ramus of nearly uniform width, with inner marginal process very slightly developed; dorsal ridge present, as in females, but more nearly over inner margin; terminal seta not swollen at base or otherwise conspicuously modified; outer terminal seta much larger than in female, more than half as long as middle seta.

*Appendages of head.* First antenna of female 8-jointed, not as long as first cephalic segment, the sense club of fourth segment extending beyond tip of antenna. Fourth segment of male antenna extraordinarily



swollen, as in *crassus*. Second antenna with accessory ramus one-jointed and apparently just as in *crassus*. Mandibular palp 2-jointed.

*Swimming feet.*  $\frac{3}{3}$ ,  $\frac{2}{3}$ ,  $\frac{2(\sigma^3)}{3}$ ,  $\frac{2}{3}$ . Outer branches of all 3-jointed.

First foot alike in the sexes, endopodite 3-jointed and exceeding exopodite only by length of last segment, which bears at tip a long prehensile seta and a spine, besides the short slender seta at outer angle; exopodite with inner border seta, as well as outer border spine, on second segment and with 2 long bent setae and 2 spines on last segment; second segment of protopodite with a rather long seta at inner distal angle, as in *crassus*. Second foot with exopodite rather short and stout (the basal segment not always so short as shown in fig. 5, Pl. 13), the third segment nearly equaling in length the first two; inner border seta on second and third segments; third segment with either 2 or 3 outer border spines, one of which is subterminal (cf. figs. 5 and 5a, Pl. 13), besides terminal spine and stout spinelike seta; endopodite about as long as first two segments of exopodite, with short broad basal segment bearing a seta, and strongly tapered distal segment having 2 inner border setae, 2 terminal setae and one subterminal outer border spine. Second foot of male like that of female, except that it lacks the outer border subterminal spine. Third foot of female with exopodite larger than that of second foot, its terminal segment with 2 inner border setae; endopodite with same spination as that of second, except for having 3 inner border setae and the segments notably broader. Third foot of male very much like that of *crassus*, as figured by Schmeil, and by Sars and conforming with the figure for *wierzejskii* given by van Douwe; second segment of exopodite having the outer border spine remarkably massive, although not as much so as in *crassus*; proximal segment of endopodite with a small inner border seta, lacking in *crassus*, according to Schmeil, but present in specimens of that species collected by me in the Bois de Meudon, near Paris. Fourth foot very much as in *crassus*, the most distal inner border seta of exopodite being very stout, strongly curved inward and heavily barbed—a notable point of resemblance to *crassus*; endopodite very short, its distal segment provided with two inner border setae, 2 terminal setae and an outer border subterminal spine. Endopodite of male fourth foot much smaller than that of female, narrowed at the base, as described by Schmeil for *crassus*, but with greatly reduced spination (not, as in that species, with same spine formula as for female), inner border seta wanting and one of the terminal setae vestigial. The fourth foot of the male offers a strong point of contrast with *crassus*, as described, and as observed by me with specimens taken near Paris.

Fifth foot: Mesial expansion well developed in female, extending to middle of distal segment, with 6 marginal setae that are normally barbed; distal segment with one inner border seta, 2 terminal, the outer one bent inward, and 2 long outer border setae, the more proximal with strong curvature at base; under surface of distal segment with transverse series of spinules. Fifth foot of male with low mesial expansion bearing 2 well developed spines, the inner about twice as long as the outer; distal segment less developed than in female, the spination about the same, except that the inner apical seta is borne on a prominent proximal process, as in *crassus*.

*Spermatophore*. Small, ovoidal.

*Egg sac*. Containing in our ovigerous females 8–10 large eggs, closely pressed together.

*Length*. Female, 0.52–0.57 mm.; male, 0.49 mm.; the females only a little smaller than those of *crassus* measured by Schmeil. Mrázek (1893) gives length of immature female as 0.67 mm. Van Douwe gives lengths of females as 0.7 mm.; of males as 0.6 mm.

*Habitat and distribution*: Found in silt in a spring run at the Allegheny School of Natural History, Allegheny State Park, N. Y., in the Allegheny Mountains at an elevation of about 1900 feet. The species reported by Mrázek (1893) from several places in a wood at St. Ivan near Příbram. Van Douwe (1900) recording it from a "quellsumpfe" near Munich, notes that, like Mrázek, he has found it only in "quellschlamm," that it is a poor swimmer, and that, unlike other German harpacticoids he has observed, it never leaves the mud, even in poorly oxygenated containers in the laboratory; he adds that this may partly account for the fact that it has rarely been observed. Thallwitz (1914) found it in material received from Dresden and gives information from Kessler of Leipzig regarding its occurrence in three places in Germany (Sachsen und Schlesien). Brehm (1920) records it from springs in Holstein and Sweden. The species seems to have been recorded, then, only from Bohemia and a few places in Germany and Sweden.

*Distinctive characters*. The remarkable form of the furca is alone sufficient to distinguish the females from those of any other species. The peculiarities of the furca are less evident in males, but the greatly enlarged fourth segment of the first antenna and the massive spine at outer distal angle of second segment of the exopodite are distinctive among known American species, while the endopodite of the fourth foot is distinctive in comparison with the European *crassus*.

*Systematic position*. *Canthocamptus wierzejskii* was originally described by Mrázek (1893) from an immature female, not recognized as

such, and mature males, but in the same year it was redescribed by that author (1893a) in a paper in Bohemian, which I have as yet been unable to consult. It was next recorded by van Douwe (1900) who gave a further description and figures, in the *Zoologische Jahrbücher, Abt. für Systematik* (1903), and a brief but more informative description in the part "Copepoda" of Brauer's *Susswasserfauna Deutschlands* (1909). The last mentioned description is illustrated with excellent figures designated, presumably through error, as "nach Schmeil." I have been unable to find a reference to any publication by Schmeil that mentions this species, and one of the figures is obviously from van Douwe's earlier paper. The antenna of the female is described by this author as 7-jointed, and, apparently, was so described by Mrázek in his second publication; the immature female originally described had a 6-jointed antenna. Thallwitz (1914) found the antenna of the female indifferently 7- and 8-jointed; he refers to a communication from Erich Kessler at Leipzig, who also found both conditions of the antenna, some examples having one antenna 7-jointed and the other 8-jointed. The 8-jointed antenna of our example is, therefore, not distinctive.

Comparison of our form with the brief descriptions available gives no basis for distinction, unless it be in the form of the mesial expansion of the fifth foot of the male, which van Douwe describes as triangular, while it is well rounded in ours (Pl. 13, fig. 2). Comparison with the figures in van Douwe (1909) bring out the following differences of somewhat doubtful significance. On the furca three well developed setae are shown on outer margin (unless one represents the dorsal seta), where our examples have but 2, (Pl. 12, fig. 7); on the fifth foot of the female the outermost seta of the mesial expansion is shown widely removed from the others, while it is not so in ours (Pl. 13, fig. 12); the setae of both segments of that appendage are much longer in ours than shown in the figure of *wierzejskii*; the difference in the form of the mesial expansion of the male has already been mentioned; with the endopodite of the fourth foot of the male, the middle terminal seta in van Douwe's figure is quite long, much longer than shown by Mrázek, while in our examples it is very short, vestigial in fact (Pl. 13, fig. 10); the inner border spine of that member is distinctly removed from the end in the figures of van Douwe and Mrázek, but virtually terminal in ours.

None of the previous authors seem to have been impressed with the notable resemblances between *wierzejskii* and *crassus*, although Chapuis (1929a) leaves only *crassus*, *wierzejskii* and *nakaii* in the subgenus *Attheyella* s. str. It is true that the furca offers a conspicuous point of

distinction, the tendency to distortion of this member, shown notably in *crassus*, being carried to a remarkable extreme in *wierzejskii*; in the males, too, the fourth foot, as compared with that of *crassus*, is, in the other species, highly modified in the direction of reduction. Other points of distinction displayed by *wierzejskii* seem rather minor: form of body, armature of abdominal segments, form of apical furcal setae, possession of an inner border seta on proximal segment of endopodite of third foot of male.

Notable points of similarity to *crassus* are: the extremely enlarged fourth segment of the antenna of the male, the relatively long seta on distal segment of protopodite of first foot, the massive spine on second segment of exopodite of third foot of male, the stout and strongly curved distal inner border seta of exopodite of fourth foot, the prominent process supporting the inner apical seta of distal segment of fifth foot of male—a significant group of special features.

The evolutionary plasticity of the furca of harpacticoid copepods is nowhere better exemplified than in this species and in *bidens* Schmeil. Indeed, the present species may aid toward an understanding of the relationship of *bidens* and its subspecies and relatives, which have been placed by Chappuis (1929a) in a separate genus, *Elaphoidella*. If a species that is almost identical with *crassus* in so many respects can show such extreme specialization in the furca as does *wierzejskii*, then the less notable, although striking, peculiarities of the furca of *bidens* and its relatives offer the less reason for taxonomic isolation. Accordingly, while the present species is probably no closer to *bidens* than is *crassus*, it yet tends to link the three species by suggesting that the diverse forms of furca displayed by them—*crassus* with dorsal ridge and external lateral process, *bidens* with dorsal crest and prominent hooks, and *wierzejskii* with dorsal ridge, external lateral process and highly specialized internal process—are not inconsistent with close relationship. We now question, even more than formerly, whether there is a valid basis for the genus *Elaphoidella*.

#### *Attheyella idahoensis* (Marsh)

*Canthocamptus idahoensis* Marsh, 1903.

#### Plate 14.

A fairly large and crassly armed and sculptured copepod, described by Marsh from Alturas Inlet, Idaho, possesses several very peculiar characters. Unfortunately, as Marsh recognized, it is imperfectly de-

scribed, because of inadequacy of material. Of the original material, there seem now to be available only two slides, one (No. 930 of the Marsh collection in the United States National Museum), containing part of a dissected female, and one (No. 931), parts of a dissected male—assuming that these are of one species. As will be shown later, the other slides catalogued as representing this species are either doubtfully of the species, or certainly not of it. Two male copepods found in material from Devil's Lake, Montana, furnished me by Professor R. T. Young, conform so perfectly with the available type material of the male, that I regard their identification with *idahoensis* as hardly to be questioned. They depart notably from Marsh's *description* in respect to the second and fourth feet—parts that are now missing from the type material as represented on slide No. 931—but there is strong reason for believing that these parts were missing when Marsh wrote the description, and that they were described from material that should not have been identified with the species.

Marsh's slides have been made available to me by courtesy of the United States National Museum. His manuscript catalogue cites his slides Nos. 930, 931, 932, 992, and 3594. Slides 932 and 3594 comprise parts of immature copepods from Alturas Inlet (the type locality of *idahoensis*), but I think these are doubtfully to be identified with the species in question. This leaves: slide No. 930, comprising first antennae, antennule, first feet, fifth feet, a separate foot, and two incomplete pairs of feet of a female ("egg-bearing"); slide No. 931, comprising third feet, fifth feet, two separate exopods, abdomen and parts of body of the male whose furca and fifth feet are figured by Marsh; and, finally, slide No. 992, comprising second (?), third, fourth (?), and fifth feet, abdomen and mouth parts of a male copepod labeled "*Canthocamptus*-Alturas", but most certainly not of the same species as the copepod on slide No. 931; the third foot is different, the fifth foot is decidedly different (see our text fig. 7 and contrast with Pl. 14, figs. 5, 6, and 8), and the peculiar abdomen, with very short furca, is altogether unlike that of *idahoensis* as described and illustrated with remarkably long and slender furca. Marsh knew copepods much too well for it to have been possible for him deliberately to have identified the copepods of slides 931 and 992 as one and the same, and yet one of the pairs of feet (second feet?) on this slide is unmistakably the model for his fig. 8, for second foot of male (cited in text as fig. 10), a drawing that seems quite inappropriate for *idahoensis*. His description of the fourth foot of the male is believed to have been derived also from that slide. The

most likely explanation of the confusion would presuppose the combination of two sets of drawings not originally intended for the same species and later entries in the catalogue based on the erroneous identification of the numbered drawings with a single species.<sup>8</sup>

There may even be a doubt as to whether the female of slide No. 930 is of the same species as the male of slide No. 931. It could not be assumed to be such if Marsh were correct in representing the furca of the female as of the same form as that of the male. But Marsh's fig. 1,

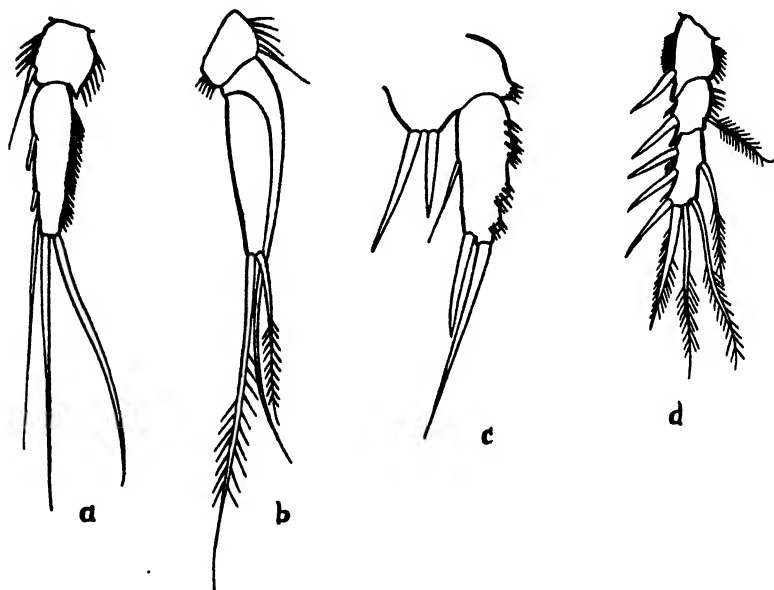


FIG. 7. *a*, Endopod of second (?) foot of unknown male of Marsh's slide No. 992; *b*, endopod of third foot of same; *c*, fifth foot of same, incomplete; *d*, exopod of third foot, less highly magnified.

called "furca of female", must be assumed to be drawn from the male rather than from the female; the accidental distortion of the furca and its mutilation as regards the apical setae of one branch identifies the

<sup>8</sup> Some confusion in regard to the figures undoubtedly occurred, for Marsh's figure references in the text do not correspond in any instance with the figure numbers on the plate, or with his list of figures. Subtracting 3 from the reference number given in the text gives the proper figure number on the plate and list in most cases, but not in all.

drawing unmistakably with the furca of slide No. 930, labeled "♂" and having other parts of the male; in form and armature, barring the distortion and mutilation, it corresponds closely with the furcas of my males. The furca of slide No. 930 is certainly different, although its form cannot be accurately discerned in the mount. Difference in form of furca between the sexes is not unusual, and the sculpture of the abdominal segments seems to relate the female very closely with the male of slide No. 930, while precluding identification with the other male. Comment must, however, be made on the unusual difference in size in the fifth feet of male and female, as illustrated in text-fig. 8. Another occasion for comment is offered by the lack of evidence of fusion of the first and second abdominal segments of the female.

Certainly two, if not three, species are represented by the three slides, and all three slides were evidently used in the description and illustration of the species. The question then arises: Which shall be taken as the type of *idahoensis*? Since Marsh placed most emphasis on the length and form of the furca (exemplified on slide No. 931), and on the unusual elongation of the fifth feet of male and female (not applicable to the male of slide No. 992), and since the characters of the female remain as yet quite imperfectly known, while the male can be described with reasonable adequacy from slide No. 931 and my additional material, it seems best to assume that the type material of the species comprises the parts of a male on slide No. 931 of the Marsh collection in the National Museum and that the parts of the female on slide No. 930 of the same collection should be regarded as representing a paratype.

The second and fourth feet of the male are probably as represented, not altogether completely, in my figures. My material, on 6 slides, is deposited in the United States National Museum. Five slides contain parts of one male: (1) first and second feet, (2) second foot, dorsa, etc., (3) third and fourth feet, (4) parts of second, third, and fourth feet, and (5) fifth feet and abdomen: the sixth slide comprises a male, with only the antennules, mandible, first feet and exopod of fourth foot dissected off, but present. It is undesirable to dissect this example further until additional material is available.

In the circumstances mentioned, our material justifies correction, as well as some amplification of the description of the species. The following description, applicable primarily to the male, is based on Marsh's text, his type material, and my material; but all significant deviations from the original description are distinctly mentioned as such.

*Form of body.* Body of the male stocky, with comparatively little

taper from cephalothorax to last abdominal segment. Posterior margins of all abdominal segments, except the last, deeply and coarsely dentate; "two dentations, one on each side, are especially prominent on the abdominal segments" . . . these prominent teeth I find on the first, second, and third abdominal segments, those on the first two terminating remarkably pronounced lateral keels (Pl. 14, figs. 1 and 9); submarginal series of fine short spinules on sides of abdominal segments incomplete dorsally, but completed below on segments 2, 3, and 4; several transverse series of very fine spinules on abdominal segments 2-5.

*Anal plate.* Evenly rounded, with bare margin.

*Furca.* Extremely long and slender in the male, sharply narrowed at about half length, where there are two lateral setae, a group of small spinules and the dorsal seta; a prominent dorsal crest extending from base of furca to base of dorsal seta; middle apical seta well developed, the lateral short, equaling half length of furca, the mesial quite short. Marsh does not mention a difference between the sexes in respect of form of furca, but the furca on his slide No. 930 ("♀, egg-bearing") is shorter than that of the male and of apparently different form; it can not be studied carefully without remounting, which would entail risk of the loss of various small parts.

*Appendages of head.* First antenna of female "8-jointed, and of the form typical for *Canthocamptus*. The first four segments are much larger than those which succeed, and are of approximately equal length. The relative lengths of the segments, commencing with the first, are as follows: 25, 23, 31, 24, 7, 15, 8, 20. The first three segments have circlets of small spines. The sensory seta of the fourth segment extends beyond the end of the eighth segment. The seventh and eighth segments are somewhat indistinctly separated. The first antenna of the male is composed of seven apparent segments, of which the first three are very much swollen." [Presumably Marsh counted as the third segment what is now generally called the fourth; the exceedingly prominent fourth segment of the antenna of the male is very like that of *crassa* or that of *wierzejskii*]. Second antenna, 1-jointed with 4 setae. Mandibular palp long, slender, 2-jointed.

*Swimming feet.*  $\frac{3}{2}, \frac{2}{3}, \frac{2(\sigma^3)}{3}, \frac{2}{3}$  (female according to Marsh). Endopod of first foot strongly prehensile, the first segment about equaling exopod; sub-apical inner border seta of each segment of endopod, and of second segment of exopod with long slender, hair-like barbs. Endopod of second foot armed, according to Marsh, with two terminal setae and



with two lateral setae in female, three in male [?]  
—we find two terminal setae, a subterminal outer border spine, all stout, and a notch on the inner border which may represent the seat of a lost seta. Endopod of third foot of male with process on second segment more than twice as long as distal segment; distal segment with two apical setae, one very long, the other short and coarsely barbed; second segment of exopod with sub-terminal outer border spine very strongly developed, this exceed-

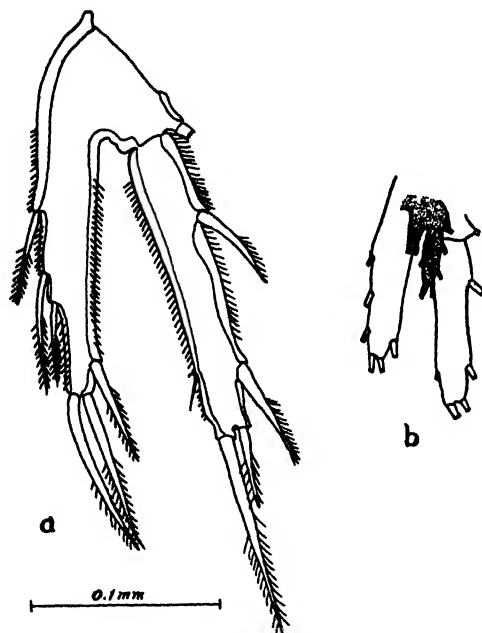


FIG. 8. *a*, Fifth foot of female of Marsh's slide No. 930; *b*, fifth feet of male of slide No. 931 (*idahoensis*) and of female of slide No. 930, superimposed to show great difference in size—foot of male, shaded, drawn to same magnification as that of female, shown in outline.

ingly stout spine constituting another notable point of resemblance to *crassa* and *wierzejskii* (Marsh's figure and mine are almost identical). Endopod of third foot of female, according to Marsh, with two terminal and three lateral setae.

As to the fourth feet, the distal segment of the endopod, according to Marsh, has in the female three terminal setae, and in the male three terminal and two lateral setae [?]. The fourth foot in my examples has

only the three terminal setae and some lateral spinules. For reasons previously given, Marsh's description and illustrations of the armature of the second and fourth feet of the male must be assumed to be based upon a confusion of material.

Fifth feet: "The fifth feet in both male and female are unusually elongated. In the male (Plate IX, fig. 12 [9]) the outer part consists of a slender segment armed on the exterior margin with two stout spines, a short and a long spine at the apex, and a slender seta about midway of the interior margin. The inner part of the foot is quadrangular, and armed at the apex with two stout spines of which the inner is twice as long as the outer" [compare Pl. 14, fig. 8].

"The two parts of the fifth foot of the female (Plate IX, fig. 13 [10]) are nearly equal in length, and are long and slender, the length being about six times the width. The outer part is armed like that of the male, but the spines are weaker and the seta on the internal margin is on the apical portion of the segment. The inner part of the foot is armed with six setae, of which two are apical, one external, and three internal." (Marsh) [The description is good if Marsh was correct, as we assume that he was, in identifying the female of slide No. 930 with the male of slide No. 931. See text fig. 8a].

In every particular in which my males can be compared with Marsh's material, the conformity is remarkably close, and this includes all the highly distinctive features of the male of this very singular copepod.

*Length.* "Length of the male 0.7 mm." (Marsh); my males 0.72 and 0.685.

*Habitat.* Known as yet only from Alturas Inlet, Idaho, and Flathead Lake, Montana.

*Distinguishing characters.* The remarkably long slender furcal rami, the fifth feet of male (and female?) with high (particularly in female?) and narrow mesial expansion of basal segment and very long narrow distal segment, the strong spine on the second segment of the exopod of third foot of male and the large fourth segment of the first antenna of male, the last two characters being shared with *wierzejskii* (Mrázek) and *crassa* Sars.

*Systematic position.* The peculiar form of fifth feet and furca and the lateral keels on the abdomen make the species very difficult to place with reference to others, especially while information regarding the female is so incomplete. It conforms with species of the genus *Attheyella* in the conspicuous dentation of body segments and the 1-jointed accessory branch of second antenna, and it closely resembles *A. crassa* (Sars) and

*A. wierzejskii* (Mrázek) in form of male antenna and third foot of the male, especially in the remarkably strong spine on second segment of exopod. It is like those two species and like *bidens* Schmeil in having a strongly developed keel-like ridge on each branch of the furca, although the keel is differently placed in the several species. The extreme length of the furca and the scant development of the outer apical seta are in contrast to conditions in *crassa*, but the outer apical seta of *wierzejskii* is intermediate between that of *crassa* and that of *idahoensis*. The furcas of *crassa*, *wierzejskii*, *bidens* and *idahoensis* are very different in form, but at least they have in common the peculiarity that they are all so highly modified as to be bizarre in appearance. For the present, I think that *idahoensis* is to be associated with those species.

*Attheyella* (*Elaphoidella*) *bidens* (Schmeil) *coronata* (Sars, 1904)

*Canthocamptus bidens* Schmeil, 1893b.

*Attheyella coronata* Sars, 1904.

*Attheyella caroliniana* Coker, 1926.

*Elaphoidella bidens* (Schmeil) *coronata* (Sars), Chappuis, 1930.

#### Plate 15

In an earlier paper (Coker, 1926) I presented description and illustrations of a copepod from Lake James in western North Carolina as a new species, *Attheyella caroliniana*. Brady's genus *Attheyella* at that time was understood to differ from *Canthocamptus* in several characters, more particularly in the reduction of the endopodites of the legs, the second and third legs as well as the fourth having endopodites on two instead of three joints. Sars (1911) expressed a doubt as to the validity of the genus, but continued its use. Since that time Chappuis has shown the lack of validity of the genus *Attheyella* as distinguished by Brady, but has reestablished the generic name with a modified significance. He has also pointed out the near identify of my species with Schmeil's *bidens* and has identified it with Sars's *Attheyella coronata*, to which he gives subspecific rank. For *bidens* and some other species he established the genus *Elaphoidella* (see p. 81 above). Our form agrees with Schmeil's *bidens* in most of the highly characteristic features: The remarkable lobes on the dorsal side of the furca, one of which is distinctly hooked (both shown by Schmeil as hooklike), and the other topped by a series of hairs; the peculiar form of the accessory branch of the second antenna, which is short, unsegmented, terminally broadened, and provided with 4 short-barbed setae; the toothlike projections between the setae on the mesial expansion of the fifth feet; the midway spines on ventral side

of next to last abdominal segment; and the remarkably long terminal setae of the endopodites of the second and third thoracic legs. All these characters except the last are shown on the accompanying text fig. 9.

Our form differs from Schmeil's *bidens* in no notable particulars except the following: The endopodite of the first foot is 3-segmented and not 2-segmented; the endopodite of the third leg has 3 setae on inner border, instead of resembling the endopodites of the second and fourth feet with 2 setae on the inner border; the 4 setae of the mandibular palp are not all terminal, 1 or 2 of them arising laterally; the genital segment has a more extensive development of the lateral series of subterminal

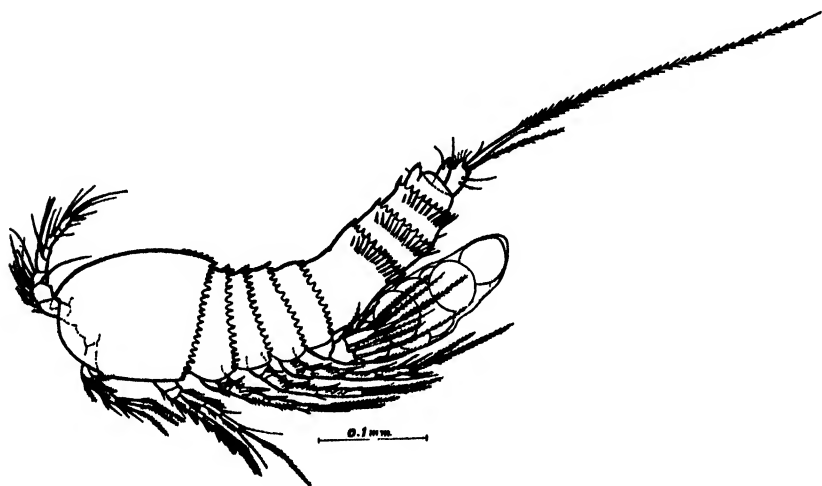


FIG. 9. *A. bidens coronata* Sars. Female with eggs, from Lake James, N. C.

spines. The first character mentioned would seem to be one of considerable significance, but as I have found variations in the segmentation of the endopodites of the second feet of another species (*illinoisensis*), that character, notable as it is, can not be given specific significance.

In the first two of the characters mentioned above, our form shows perfect agreement with Sars's *coronata*, described from Hawaii, as well as in practically every detail of spination of feet.

The species is a remarkable one in many ways. Among the fresh-water harpacticids we have seen, it is the most readily distinguished by its obvious external characters. It is apparently one of the most widely distributed species, being recorded from Germany, England, Ceylon,

New Guinea, South and North America, and elsewhere (Chappuis). It seems to be almost everywhere one of the rarest of copepods. Schmeil had but two examples. Gurney has remarked by letter on its extreme rarity in England, and others have reported it as rare in other regions. I have found it relatively abundant in Lake James in western North Carolina and have taken single examples in a marsh and in two runs near Chapel Hill and in an artificially formed swimming pool, near Bradford, Pa.—always by chance. The most thorough and deliberate searches have failed to yield a single specimen even when looking in places where it had previously been taken by chance (there has been no opportunity to return to Lake James). Only females are ever found, males remaining unknown. Roy (1931) has recently shown that the species reproduces parthenogenetically. Therefore, in addition to the peculiarities of form and distribution, it offers the only recorded instance of parthenogenesis among copepods. Males were unknown until described by Chappuis (1931a) from Sumatra and Java.

The form found in North Carolina has been fully illustrated in my earlier publication cited. For the sake of completeness we include here an outline sketch of the whole animal (fig. 9), figures of the appendages (pl. 15, after Coker, 1926, pl. 43), and a brief diagnosis for females. (See also Coker, 1926, for illustrations of mouth parts.)

Anterior part of body little wider than hinder part; posterior border of all dorsal plates deeply and irregularly toothed; plates roughened by transverse series of fine spinules; conspicuous whorl of flaring spines near posterior border of first 3 abdominal segments, with broad gaps on dorsal side; some large spines about midway of next to last abdominal segment on ventral side; anal operculum bordered with very fine spinules; the rather short caudal furca with 2 prominent projections on dorsal side, the more anterior being high, pointed, and more or less hooked, the more posterior lower, hooked or rounded, and bearing a series of hairs on top; 3 very unequal terminal setae, the middle very strongly developed, the mesial smallish but distinct.

Antennae short, 8-segmented; antennule with 1-jointed accessory branch, which is short, widened at tip, and armed with 4 short-barbed setae. First foot with 3-segmented endopodite, little longer than exopodite. Second foot with 2-jointed endopodite, the first segment having 1 seta on inner border, the second having 2 setae on inner border, and 2 very long terminal setae with a long slender spine. The third foot like the second, except that the inner border of the distal segment of each branch has one more seta. The fourth foot, armed like the third, except

that the proximal segment of the very short endopodite has no seta, and the distal joint lacks one of the setae of inner border and one of the terminal setae. Fifth feet with low mesial expansion of proximal joint bearing 4 long setae, between which are toothlike projections of the chitinous integument; the distal joint long, subrectangular, with 2 setae and short spines on outer border, 2 long terminal setae, and 1 seta and some spines on the inner border.

*Length.* About 0.43 mm., our smallest known species.

*Habitat and distribution.* Taken in some numbers in plankton in upper end of Lake James in western North Carolina and, near Chapel Hill, very rarely in a marsh at Glen Burnie and in a small stream south of the campus; also in a pool near Bradford, Pa. The subspecies is recorded also from Ceylon and the Malay Archipelago (Daday), New Guinea and the Hawaiian Islands (Sars), and South America (Douwe, Daday). The species as more narrowly limited is recorded from Germany (Schmeil), France (Jakubisiak, Roy), and England (Scourfield, Gurney—personal letter).

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## PLATE 1

### CANTHOCAMPTUS STAPHYLINOIDES SINUS n. subsp.

Fig. 1. 2d antenna of female. × 166.

Fig. 2. Furca and last abdominal segments of female, dorsal aspect. × 166.

Fig. 3. Part of furca and last abdominal segments of female, ventral aspect. × 166.

Fig. 4. 5th foot of female. × 166.

Fig. 5. Side view of female with spermatophore. × 83.

- Fig. 6. 1st foot of female.  $\times 166$ .  
Fig. 7. 2d foot of female.  $\times 166$ .  
Fig. 8. 3d foot of female.  $\times 166$ .  
Fig. 9. 4th foot of female.  $\times 166$ .

## PLATE 2

## CANTHOCAMPTUS STAPHYLINOIDES SINUS n. subsp.

- Fig. 1. Dorsal aspect of male.  $\times 78$ .  
Fig. 2. 2d foot of male.  $\times 220$ .  
Fig. 3. 3d foot of male.  $\times 220$ .  
Fig. 4. 4th foot of male.  $\times 220$ .  
Fig. 5. 1st antenna of male.  $\times 162$ .  
Fig. 6. 5th foot of male.  $\times 220$ .

## BRYOCAMPTUS HIEMALIS BREVIFURCA n. subsp.

- Fig. 7. Female, dorsal aspect.  $\times 154$ .  
Fig. 8. Antenna of male.  $\times 319$ .  
Fig. 9. Furca of male, ventral aspect.  $\times 319$ .  
Fig. 10. Furca of female, dorsal aspect.  $\times 319$ .

## PLATE 3

## BRYOCAMPTUS HIEMALIS BREVIFURCA n. subsp.

- Fig. 1. First foot of female.  $\times 291$ .  
Fig. 2. Second foot of female.  $\times 291$ .  
Fig. 3. Third foot of male.  $\times 291$ .  
Fig. 3a. Third foot of female (only endopodite shown).  $\times 291$ .  
Fig. 4. Female in side view.  $\times 196$ .  
Fig. 5. Fifth feet of male; spermatophore showing in the genital segment.  $\times 291$ .  
Fig. 6. Fifth foot of female.  $\times 291$ .  
Fig. 7. Endopodite of fourth foot of female.  $\times 291$ .  
Fig. 8. Fourth foot of male.  $\times 291$ .

## PLATE 4

## BRYOCAMPTUS ZSCHOKKEI ALLEGANIENSIS n. subsp.

- Fig. 1. Rostrum of female.  $\times 282$ .  
Fig. 2. First antenna of female.  $\times 282$ .  
Fig. 3. Second antenna of female.  $\times 282$ .  
Fig. 4. Mandibular palp.  $\times 282$ .  
Fig. 5. First leg of female.  $\times 282$ .  
Fig. 6. Endopodite of first leg of male.  $\times 282$ .  
Fig. 7. Male and female in clasp.  $\times 98$ .  
Fig. 8. Second leg of male.  $\times 282$ .  
Fig. 9. Endopodite of second leg of female.  $\times 336$ .  
Fig. 10. Endopodite of third leg of female.  $\times 336$ .  
Fig. 11. Endopodite of fourth leg of female.  $\times 336$ .  
Fig. 12. Fourth leg of male.  $\times 282$ .

- Fig. 13. Third leg of male.  $\times 336$ .  
Fig. 14. Fifth leg of female.  $\times 282$ .  
Fig. 15. Fifth leg of male.  $\times 282$ .  
Fig. 16. Furca and last abdominal segments of female.  $\times 282$ .  
Fig. 17. Furca and last abdominal segments of male.  $\times 282$ .  
Fig. 18. Anal operculum of male.  $\times 336$ .  
Fig. 19. Spermatophore.  $\times 336$ .

## PLATE 5

## BRYOCAMPUS AUSTRALIS n. sp.

- Fig. 1. Antenna of female.  
Fig. 2. Antenna of male.  
Fig. 3. Antennule.  
Fig. 4. Mandible.  
Fig. 5. First foot of female.  
Fig. 6. Second foot of female.  
Fig. 7. Second foot of male, endopodite.  
Fig. 8. Third foot of male, terminal segment of exopodite.  
Fig. 9. Third foot of male, endopodite.  
Fig. 10. Fourth foot of female.  
Fig. 11. Fourth foot of male, endopodite.  
Fig. 12. Fifth foot of female.  
Fig. 13. Fifth foot of male.  
Fig. 14. Posterior end of abdomen of female, dorsal aspect.  
Fig. 15. Posterior end of abdomen of female, ventral aspect.

## PLATE 6

## ATTHEYELLA NORTHUMBRICA AMERICANA

- Fig. 1. First foot of male.  $\times 226$ .  
Fig. 1a. Same as 1, 1st segment of endopodite, more elongate.  $\times 226$ .  
Fig. 2. Second foot of female.  $\times 226$ .  
Fig. 3. Third foot of male.  $\times 226$ .  
Fig. 4. Fourth foot of male.  $\times 226$ .  
Fig. 5. Fifth foot of female.  $\times 226$ . (Inner spine of mesial expansion unusually short.)  
Fig. 6. Fifth foot of male.  $\times 226$ .  
Fig. 7. Posterior part of abdomen, side view, female.  $\times 363$ .  
Fig. 8. Posterior part of abdomen, dorsal view, female.  $\times 363$ .  
Fig. 9. Fifth feet of male, more enlarged.  $\times 510$ .

## PLATE 7

## ATTHEYELLA ILLINOISENSIS

- Fig. 1. Female with egg sac, side view.  $\times 72$ .  
Fig. 2. Female, dorsal aspect.  $\times 72$ .

*ATTHEYELLA NORTHUMBRICA AMERICANA*

Fig. 3. Male, dorsal aspect.  $\times 141$ .

Fig. 4. Female, side view.  $\times 141$ .

Fig. 5. Antenna of female.  $\times 141$ .

## PLATE 8

*ATTHEYELLA ILLINOISSENSIS (FEMALE)*

Fig. 1. Antenna.  $\times 191$ .

Fig. 2. Antennule.  $\times 191$ .

Fig. 3. First foot.  $\times 191$ .

Fig. 4. Second foot.  $\times 191$ .

Fig. 5. Third foot.  $\times 191$ .

Fig. 6. Fourth foot.  $\times 191$ .

Fig. 7. Fifth foot.  $\times 191$ .

Fig. 8. End of abdomen, lateral aspect.  $\times 161$ .

Fig. 9. End of abdomen, dorsal aspect.  $\times 304$ .

## PLATE 9

*ATTHEYELLA ILLINOISSENSIS (MALE)*

(From Coker, 1926, with slight modifications)

Fig. 1. First foot.

Fig. 2. Second foot.

Fig. 3. Third foot; also detail of tip of chela of inner ramus.

Fig. 4. Fourth foot.

Fig. 5. Distal segment of fifth foot, drawn to same scale as other appendages.

Fig. 6. Fifth feet, more highly magnified.

Fig. 7. Inner ramus of third foot.

Fig. 8. Portion of genital plate.

Fig. 9. End of abdomen, lateral aspect.

Fig. 10. End of abdomen, ventral aspect.

## PLATE 10

*ATTHEYELLA CAROLINENSIS*

Fig. 1. Adult female.  $\times 90$ .

Fig. 2. Adult male.  $\times 90$ .

Fig. 3. Immature female, side view.  $\times 90$ .

Fig. 4. Third foot of male.  $\times 225$ .

Fig. 5. Endopodite of 4th foot of female.  $\times 225$ .

Fig. 6. Fourth foot of male.  $\times 225$ .

Fig. 7. Fifth foot of male.  $\times 225$ .

Fig. 8. Posterior part of abdomen of male, side view.  $\times 380$ .

Fig. 9. Posterior part of abdomen of male, dorsal view.  $\times 380$ .

## PLATE 11

## ATTHEYELLA CAROLINENSIS

Figs. 8 and 9,  $\times 380$ ; all others  $\times 225$ 

- Fig. 1. First foot of mature female.
- Fig. 2. Second foot of mature female.
- Fig. 3. Third foot of mature female.
- Fig. 4. Fifth foot of mature female.
- Fig. 5. First foot of sub-mature female.
- Fig. 6. Second foot of sub-mature female.
- Fig. 7. Third foot of sub-mature female.
- Fig. 8. Fifth foot of immature female.
- Fig. 9. Antennule of sub-mature female.
- Fig. 10. Antenna of mature female.
- Fig. 11. Maxillipede of mature female.
- Fig. 12. Posterior part of abdomen of mature female, side view.
- Fig. 13. Posterior part of abdomen of mature female, dorsal view.

## PLATE 12

## ATTHEYELLA WIERZEJSKII

- Fig. 1. Female with egg-sac, side view. (Transverse spination and sensory hairs not shown.)  $\times 202$ .
- Fig. 2. Ventral aspect of part of genital segment of female.
- Fig. 3. Form of body of female, dorsal aspect.  $\times 80$ .
- Fig. 4. Furca of male, lateral aspect.
- Fig. 5. Outline of spermatophore.
- Fig. 6. Furca and last abdominal segment of male, dorsal aspect.
- Fig. 7. Furca and last abdominal segment of female, dorsal aspect.
- Fig. 8. Furca and posterior part of abdomen of female, lateral aspect.

## PLATE 13

## ATTHEYELLA WIERZEJSKII

- Fig. 1. First antenna of female.
- Fig. 2. Mandibular palp.
- Fig. 3. Second antenna of female.
- Fig. 4. First foot of female, rami and distal segment of protopodite.
- Fig. 5. Second foot of female, rami and distal segment of protopodite.
- Fig. 5a. Distal segment of exopodite of second foot of female, variant form.
- Fig. 6. Second foot of male, endopodite.
- Fig. 7. Third foot of female, rami.
- Fig. 8. Third foot of male, rami.
- Fig. 9. Fourth foot of female, rami.
- Fig. 10. Fourth foot of male, endopodite.
- Fig. 11. Fifth foot of male.
- Fig. 12. Fifth foot of female.

## PLATE 14

*ATTHEYELLA IDAHOENSIS* (MALE FROM DEVIL'S LAKE)

- Fig. 1. Dorsal aspect of male.
- Fig. 2. Antennule. Second antenna.
- Fig. 3. Fourth joint of antenna.
- Fig. 4. First foot.
- Fig. 5. Second foot.
- Fig. 6. Third foot.
- Fig. 7. Fourth foot, endopod and exopod separated.
- Fig. 8. Fifth foot.
- Fig. 9. Lateral keels on second and third abdominal segments.
- Fig. 10. Outline of spermatophore.

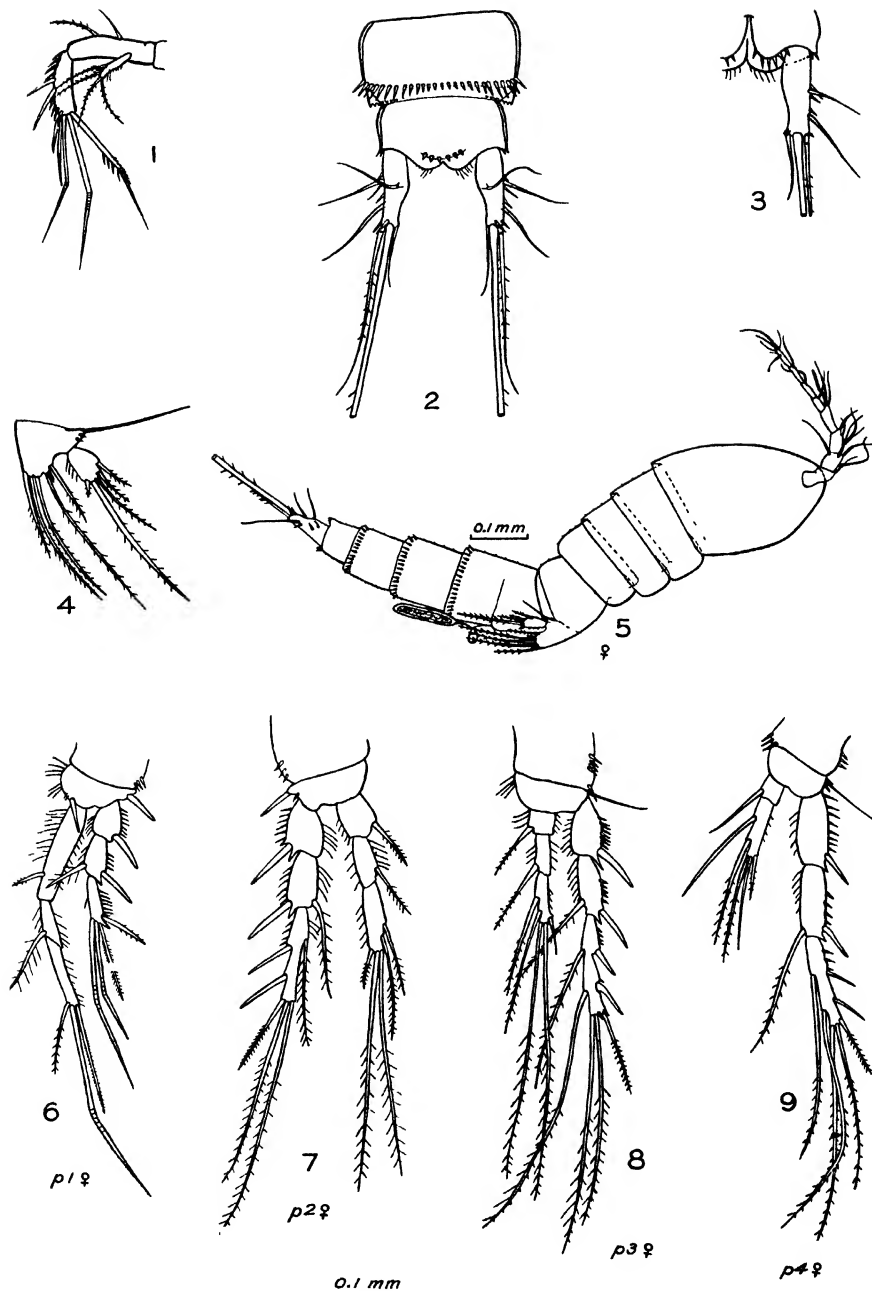
## PLATE 15

*ATTHEYELLA BIDENS CORONATA* (FEMALE)

- Fig. 1. Anterior antenna.
- Fig. 2. Posterior antenna.
- Fig. 3. First foot.
- Fig. 4. Second foot.
- Fig. 5. Third foot.
- Fig. 6. Fourth foot.
- Fig. 7. Fifth foot.
- Fig. 8. End of abdomen, dorsal aspect.
- Fig. 9. End of abdomen, ventral aspect.
- Fig. 10. Egg sac.



PLATE 1

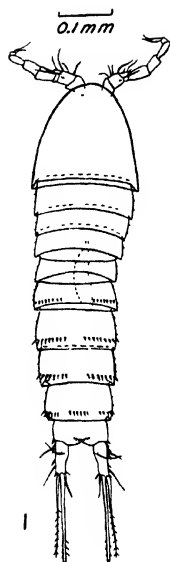


CANTHOCAMPTUS STAPHYLINOIDES SINUS N. SUBSP.





# PLATE 2



2 p2♂



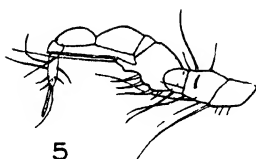
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p3♂



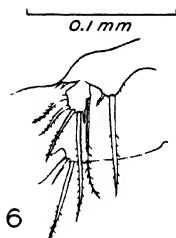
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p4♂



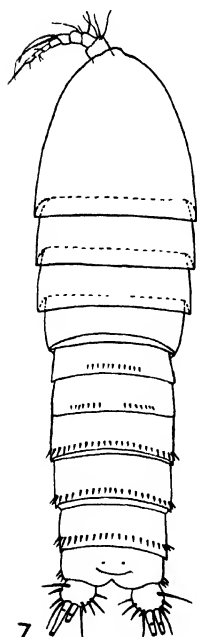
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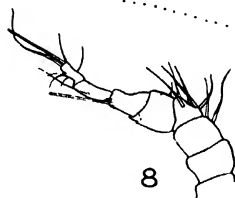
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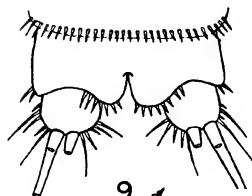


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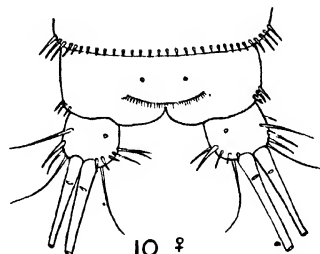
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8



9 ♂



10 ♀

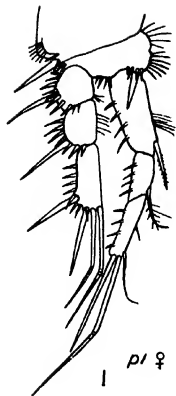
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CANTHOCAMPTUS STAPHYLINOIDES SINUS N. SUBSP.  
BRYOCAMPTUS HIEMALIS BREVIFURCA N. SUBSP.

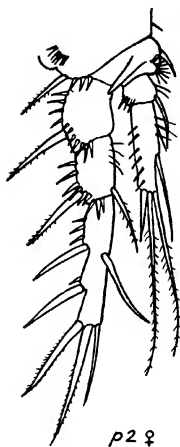


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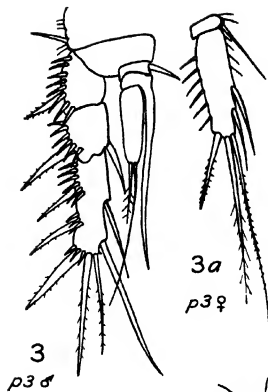
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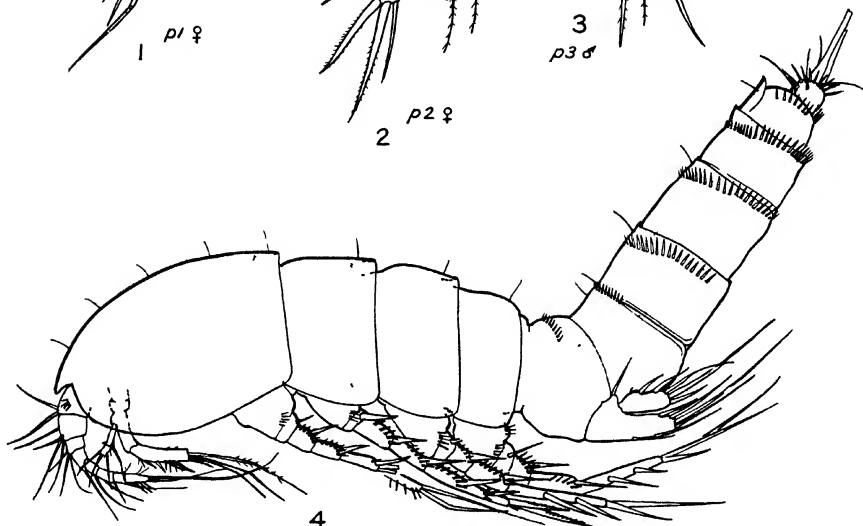
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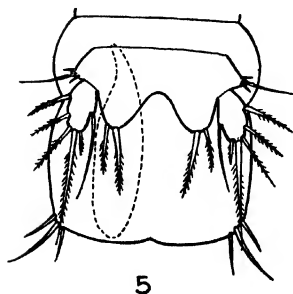
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p3 ♀

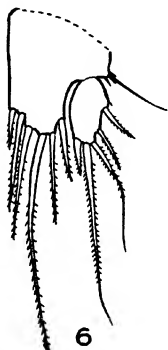


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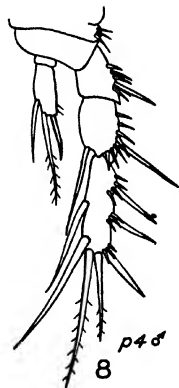


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p6 ♀

7



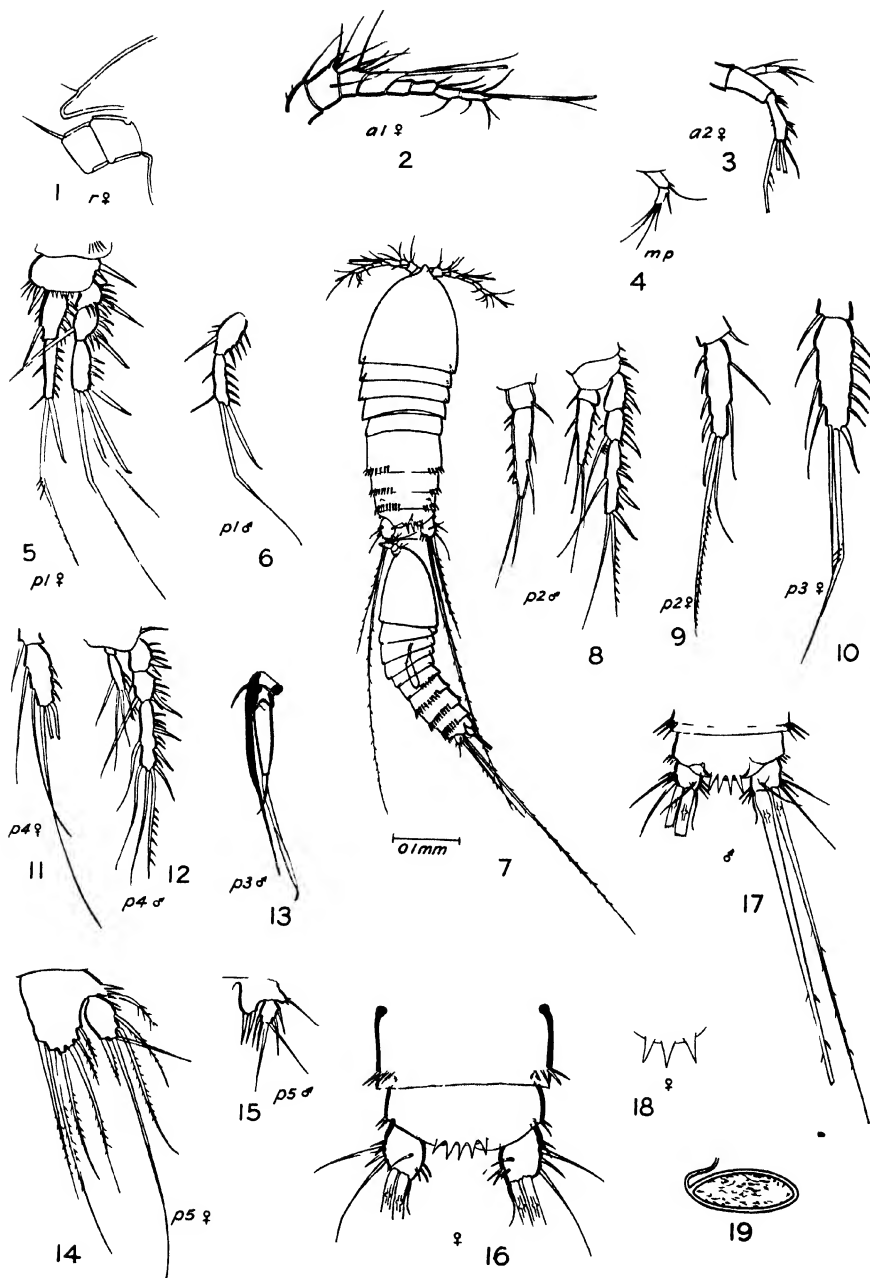
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8

BRYOCAMPTUS HIEMALIS BREVIFURCA N. SUBSP.



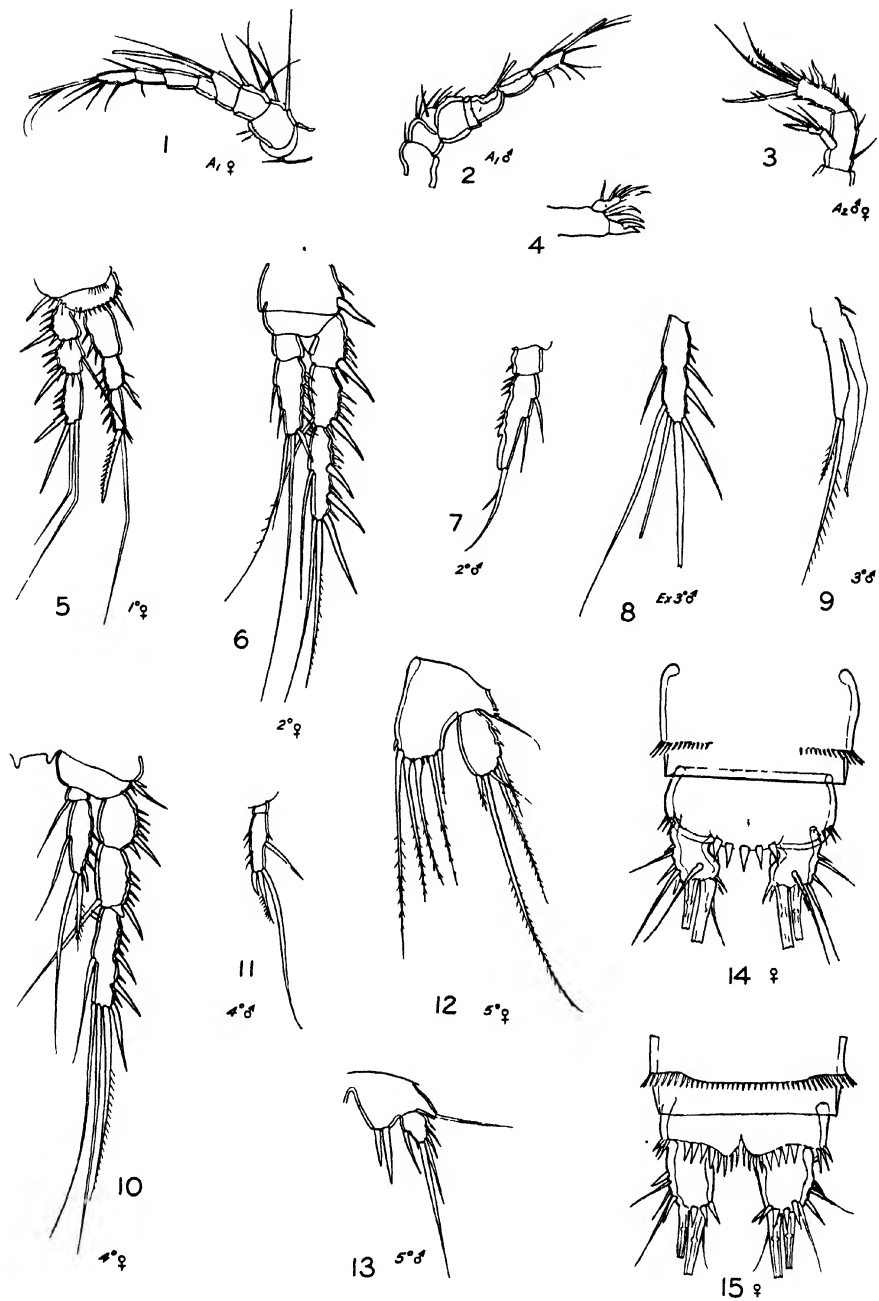
# PLATE 4



*BRYOCAMPTUS ZSCHOKKEI ALLEGANIENSIS* N. SUBSP.



# PLATE 5

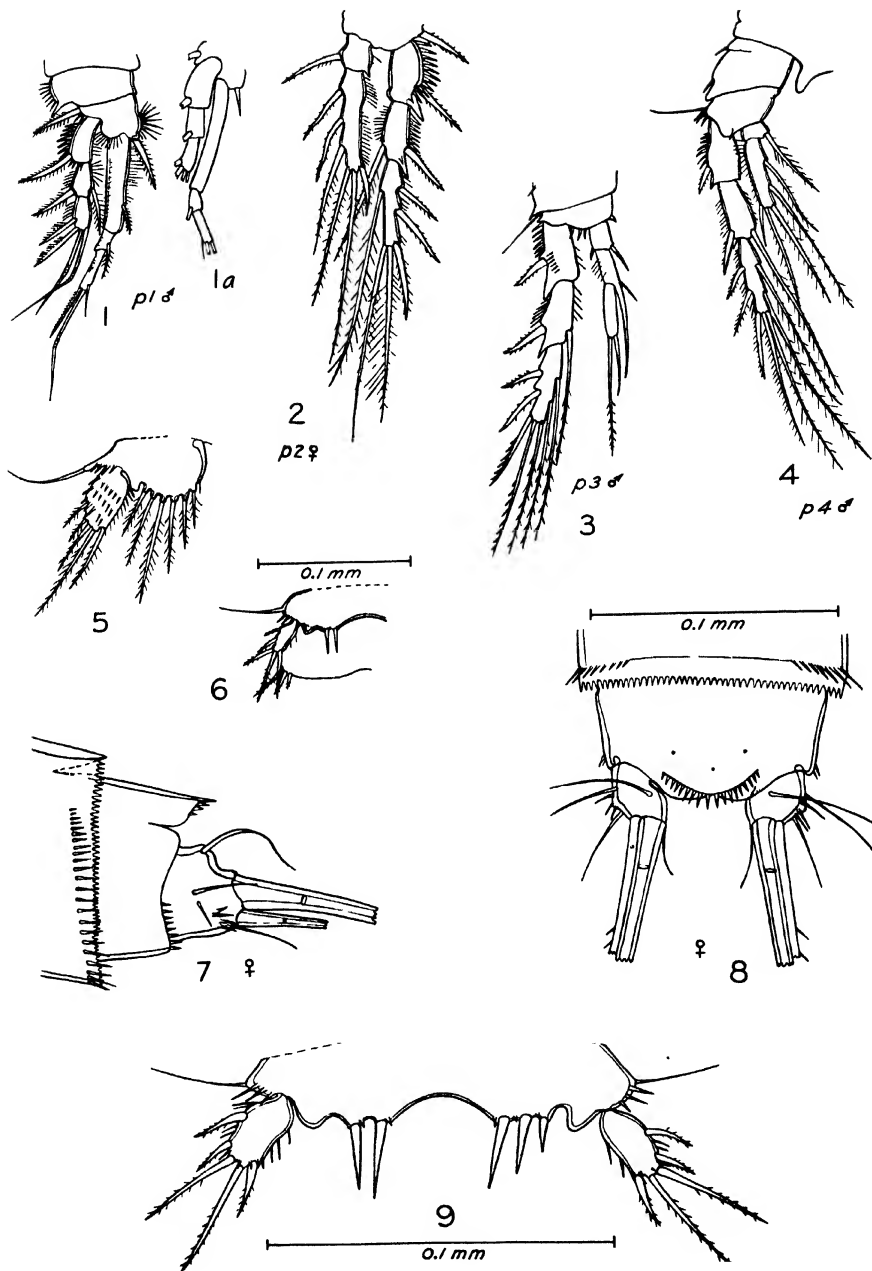


*BRYOCAMPTUS AUSTRALIS* N. SP.





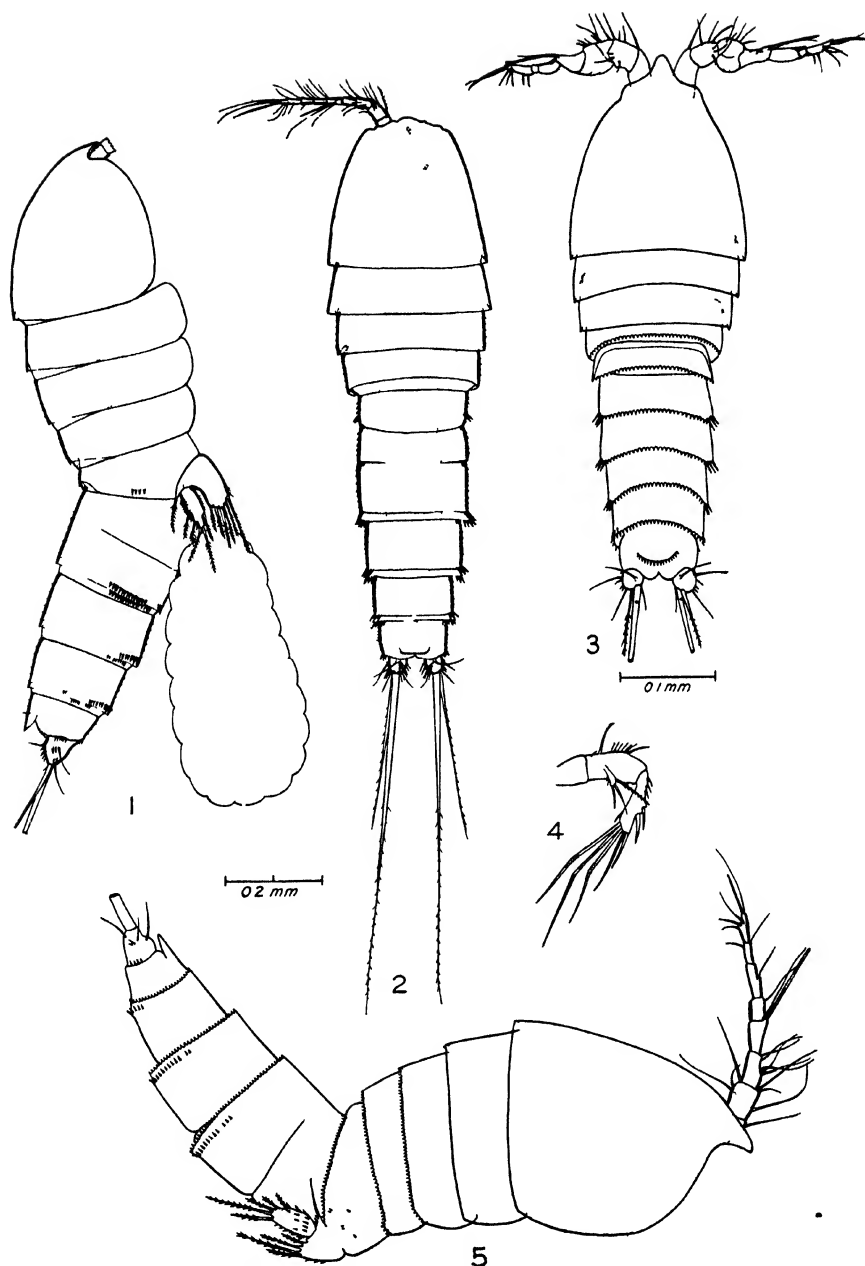
# PLATE 6



ATTHEYELLA NORTHUMBICA AMERICANA



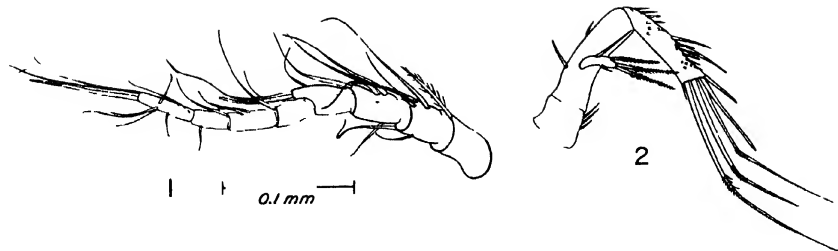
PLATE 7



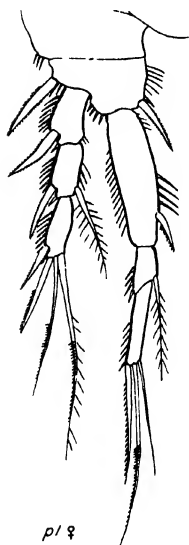
ATTHEYELLA ILLINOENSIS, FIGS 1 AND 2, ATTHEYELLA NORIHUMBRICA AMERICANA, FIGS 3-5



# PLATE 8

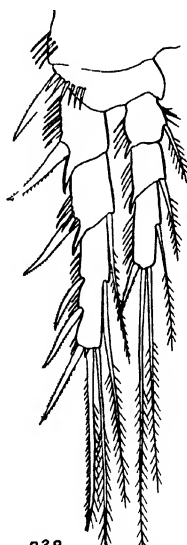


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3



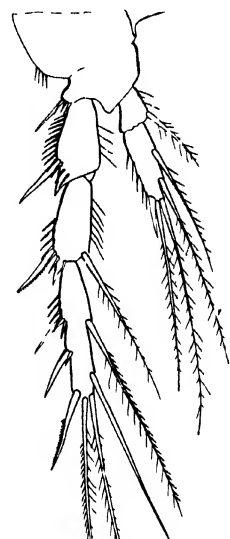
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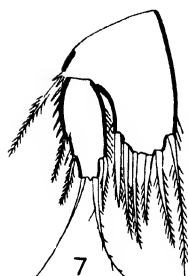
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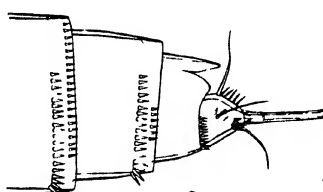


p4♀

6

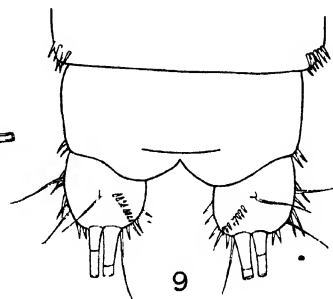


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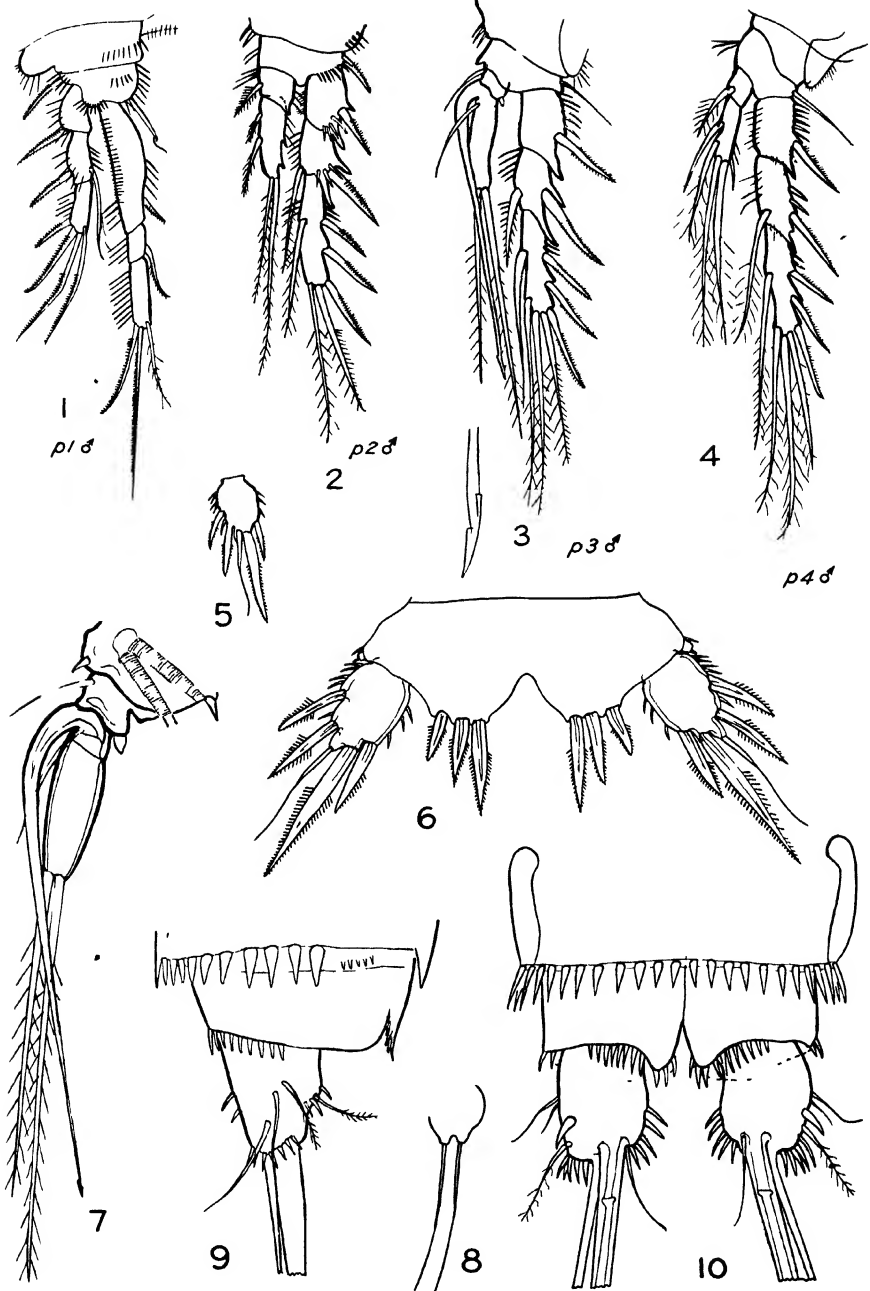
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ATTHEYELLA ILLINOENSIS (FEMALE)



PLATE 9

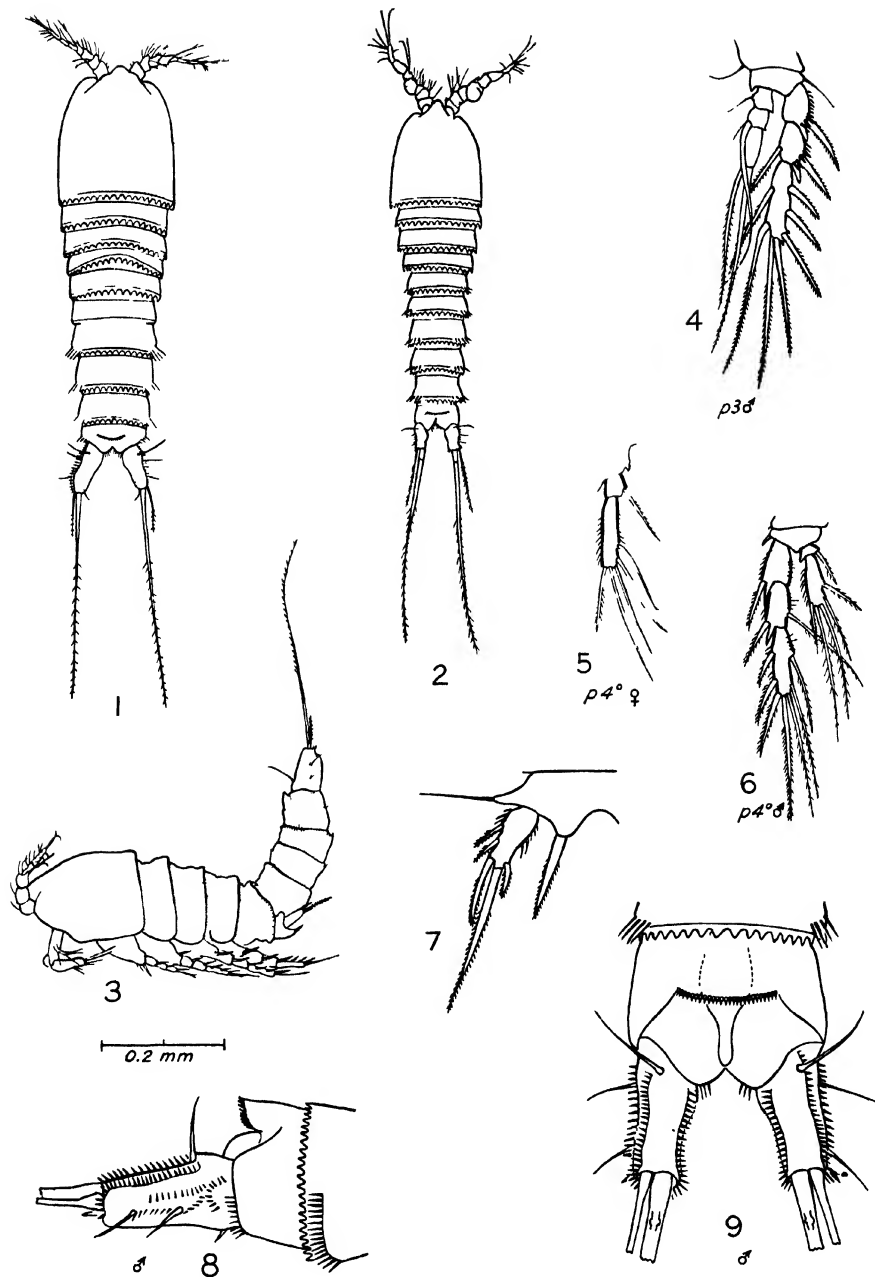


ATTHEYELLA ILLINOISENSIS (MALE)





# PLATE 10



ATTHEYELLA CAROLINENSIS



PLATE 11

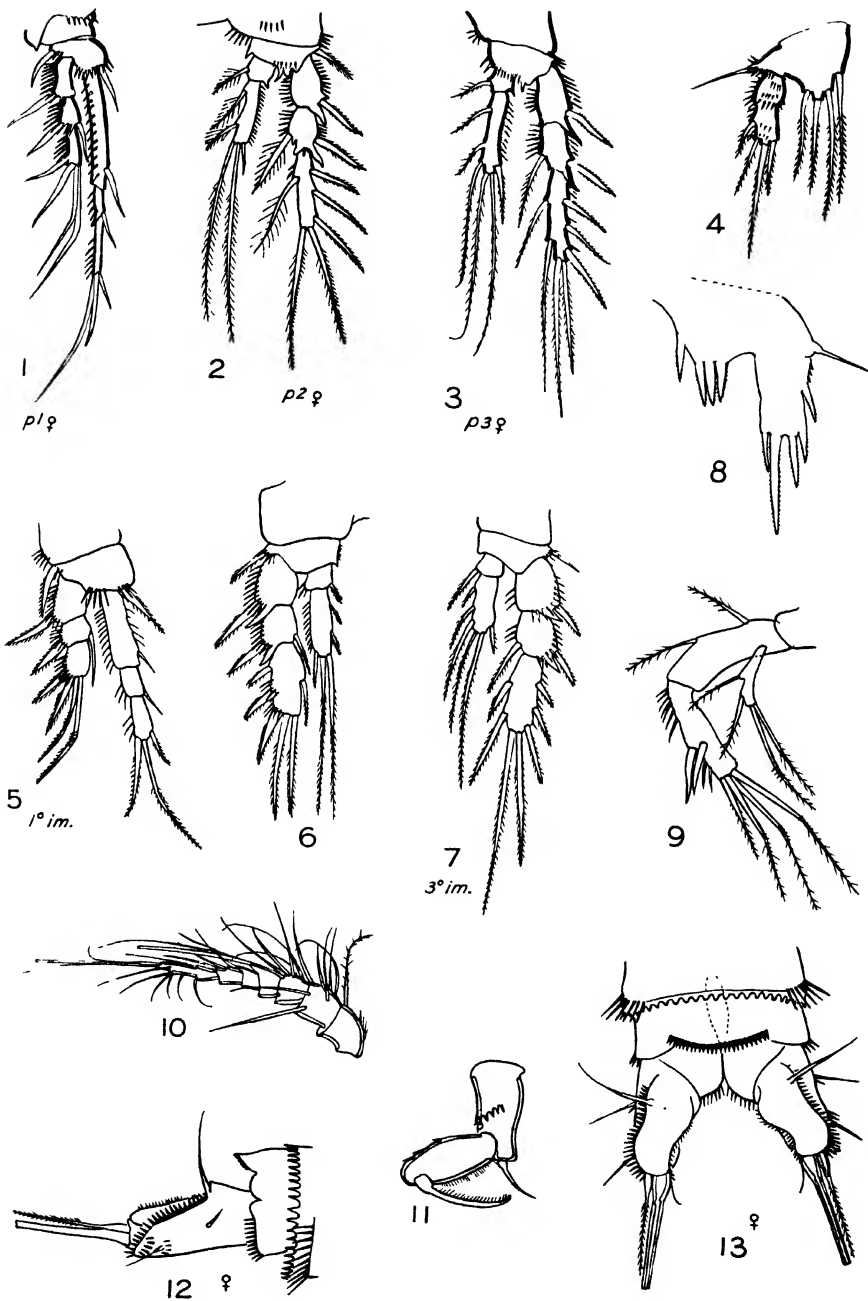
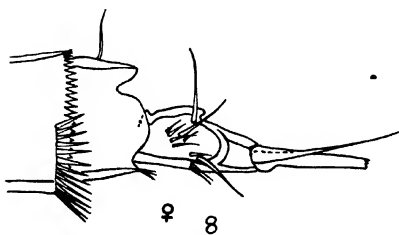
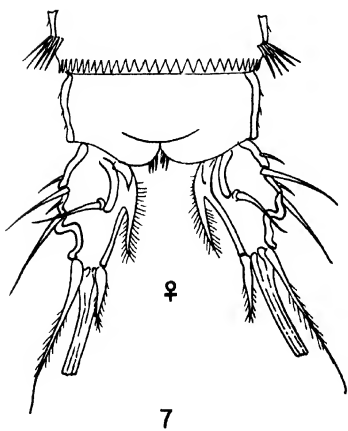
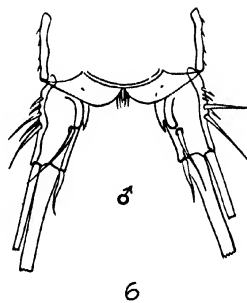
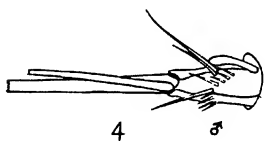
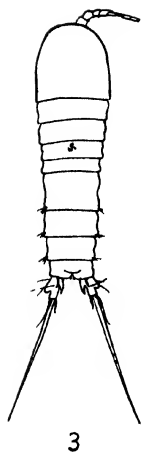
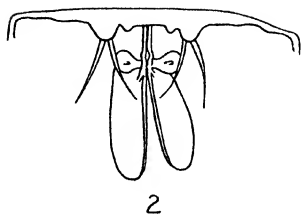
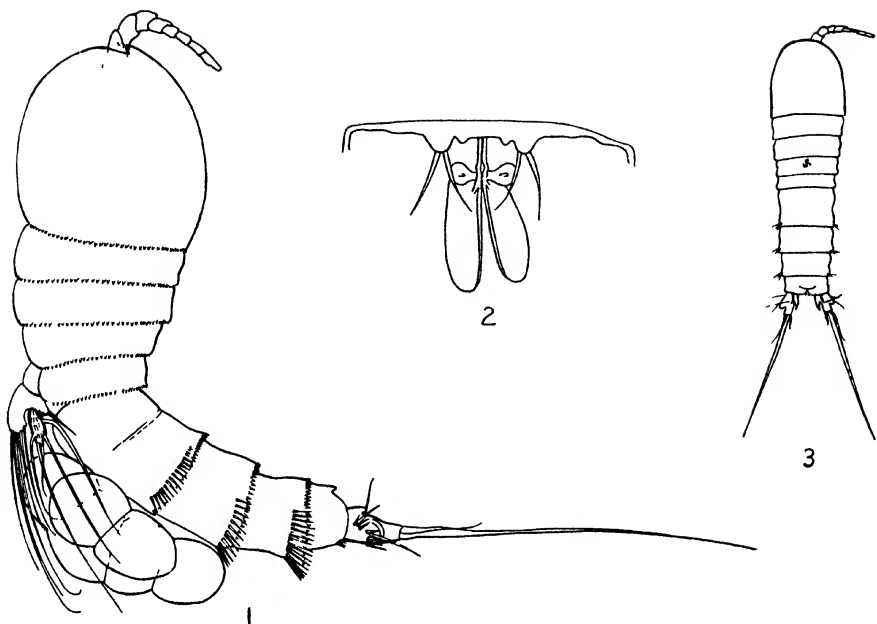


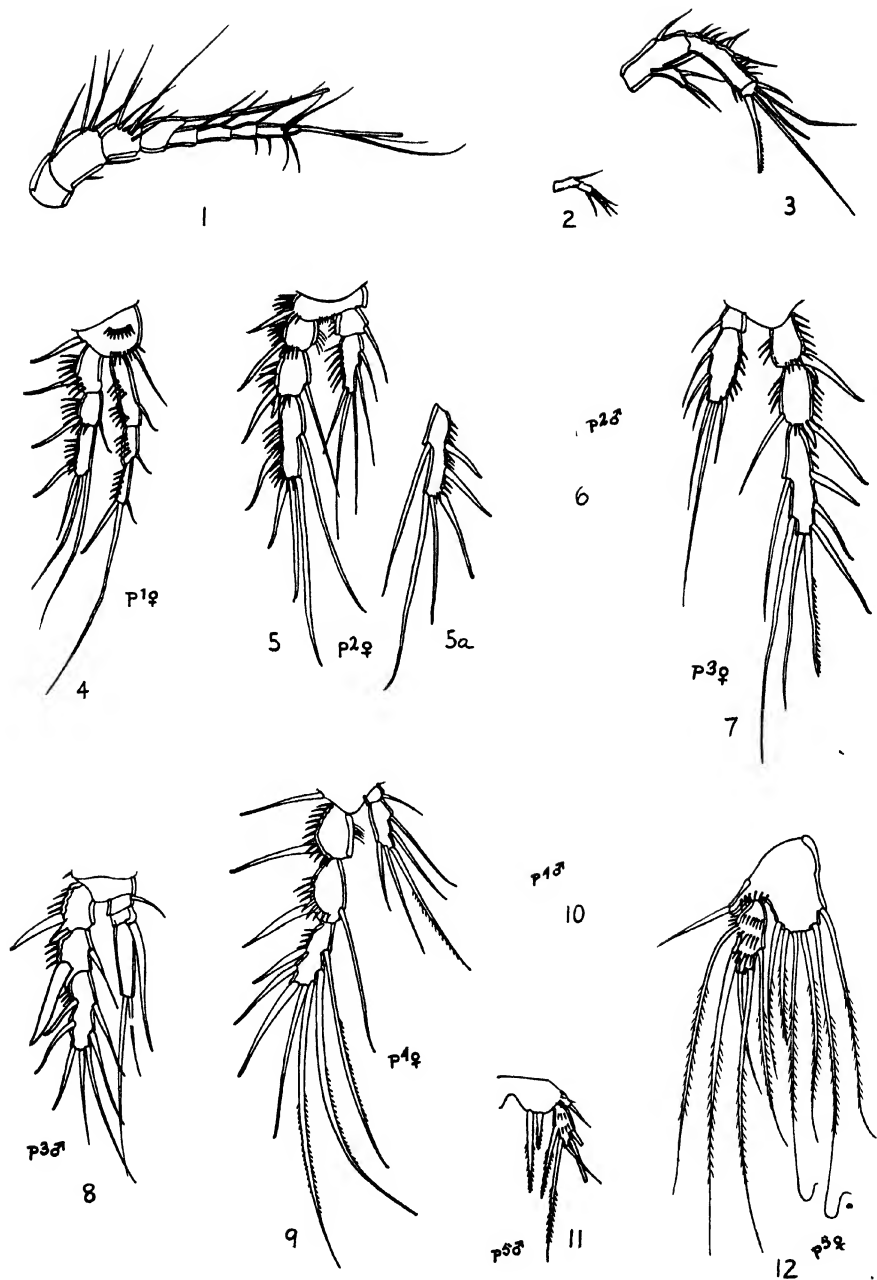


PLATE 12





# PLATE 13

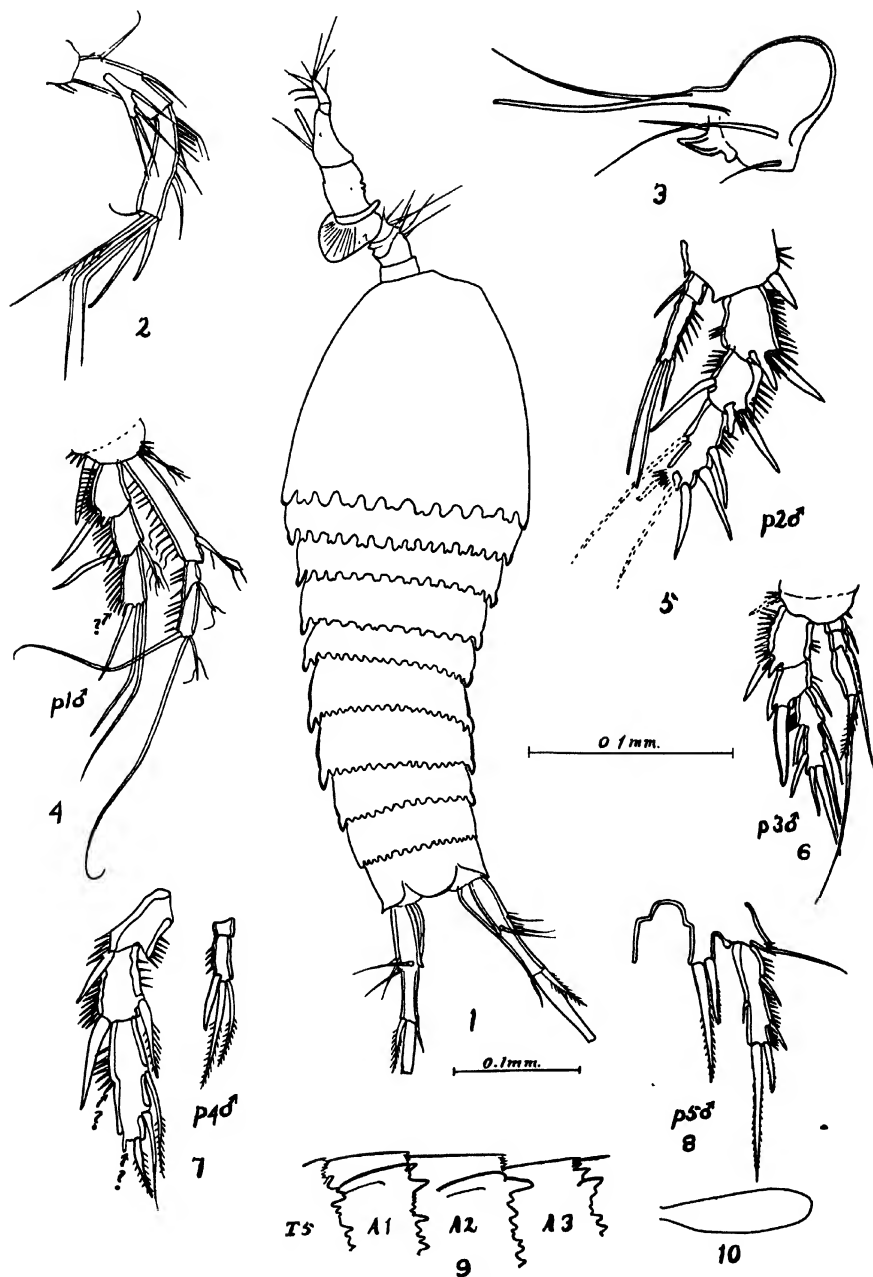


ATTHEYELLA WIERZEJSKII





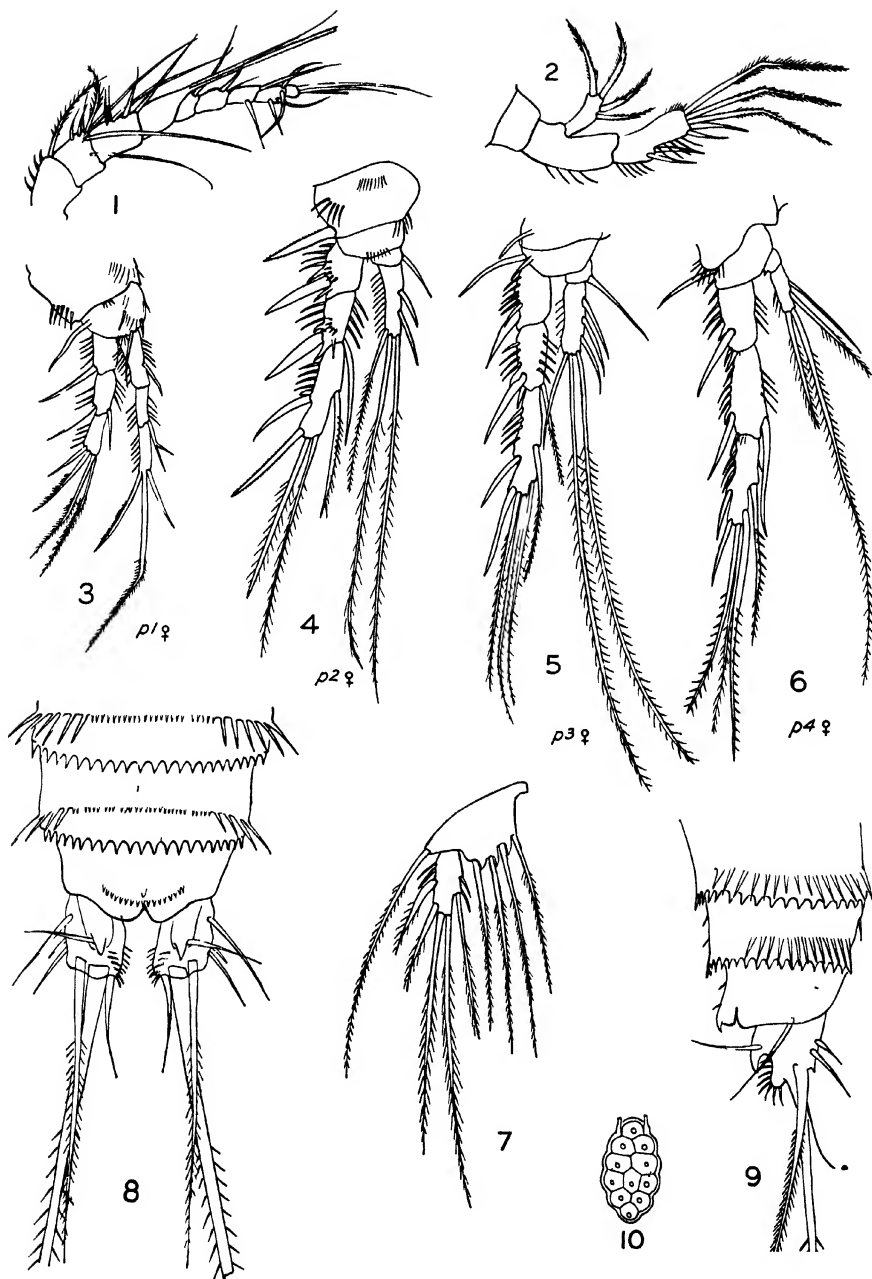
# PLATE 14



ATTHEYELLA IDAHOENSIS (MALE)



# PLATE 15



*ATTHEYELLA BIDENS CORONATA* (FEMALE)



# REACTION OF SOME FRESHWATER COPEPODS TO HIGH TEMPERATURES<sup>1</sup>

WITH A NOTE CONCERNING THE RATE OF DEVELOPMENT IN RELATION TO TEMPERATURE

By R. E. COKER

## 1 TEXT FIGURE

In connection with experiments to determine the influence of temperature on the development of freshwater copepods, it was desirable to ascertain the upper limits of tolerance of the species employed; *Cyclops viridis* Jurine, *C. vernalis* Fischer, and *C. serrulatus* Fischer. The inquiry proved more complex than had been anticipated. It was expected that a degree of individual diversity in reaction would be encountered. It was assumed also that time as well as temperature would have to be taken into consideration; theoretically, time might affect the reaction in either one of two opposing ways; on the one hand, exposure to a deleterious temperature would be expected to have a more marked effect the longer the exposure; on the other hand, should the copepod possess any capacity for adjustment, longer exposure to each of successively higher non-lethal temperatures would give the greater opportunity for the processes of adjustment and so tend to diminish the external evidences of the injurious effects of high temperatures. Put in another way, the cumulative results of physiological changes induced at high temperatures might lead to the death of the copepod at lower temperatures the longer the animal was kept at each level of dangerously high temperature, or, contrarily, internal adjustments by the animal might enable it to show a higher degree of tolerance the longer the periods of time allowed in stepping up through successively higher levels.

A third source of complexity was the fact, learned very early in the experiments, that the reaction of a copepod to high temperatures was in

<sup>1</sup> Experiments conducted in the Laboratoire d'Evolution des Etres Organisés, University of Paris, through the courtesy of Professor M. Caullery, Directeur, while I was on leave on the Kenan Foundation from the University of North Carolina. The investigation was aided by a grant from the Rockefeller Fund for Research in Pure Science at the University of North Carolina.

some measure correlated with the temperature at which the copepod had been reared, this correlation being not solely, as it appeared, the reflection of the factor of acclimatization as that term is ordinarily employed. With one exception, all our copepods had been reared at approximately known temperatures.

What had not been adequately anticipated was the extraordinary difficulty of ascertaining when a copepod was dead. We had long ago observed that individual copepods occasionally assume a condition of apparently complete inactivity, during which only repeated stimulation will bring about a manifestation of life; when, however, after a minute or two, the copepod is aroused, it may be immediately active, darting about in lively fashion.<sup>2</sup> This phenomenon was in mind and would not have occasioned special difficulty; but, in our experiments, the most serious complication came from a condition of dormancy, not immediately unlike the familiar one, but different in nature in that the copepod could not be aroused except after a marked change of conditions of temperature and the lapse of a considerable period of time. If the dormancy were only approximate or incipient, repeated mechanical stimulation might result in a simple short leap or perhaps a mere twitch of the antenna or a slight movement of the limbs; but, when dormancy was complete, no amount of stimulation, even with the animal returned to a low temperature, would induce any sign of life until after the lapse of hours or even days. For a time we had reason to assume that, when a copepod displayed the stretched form usually characterizing those that have died a natural death, it was actually dead; but occasional revivals seemed to occur even then, so that, after the first few experiments, the only accepted criterion of death was decomposition: copepods provisionally pronounced "dead" were, therefore, kept for several days and reexamined from time to time; several quite unexpected revivals occurred.

The difficulties presented by the several conditions just described will be better understood after a description of the procedure employed in the experiments.

The apparatus used was the "Bloc à séries de températures constantes," designed by Professors Cardot, Laugier, and Legendre (1924), and previously used by them in experimental work in physics. We are

<sup>2</sup> Zenker, in 1854, wrote of the "sleep" of copepods, stressing the difficulty of "awakening" them and remarking on the activity of the animals when they were aroused by mechanical stimulation; but he said that *Diaptomus castor* slept at night (!) and that *Cyclops quadricornis* did not.

especially indebted both to Professor Legendre and to Professor Caullery, through whom the apparatus was loaned for our use. The apparatus consisted of a bridge with framework of aluminum, one end to be placed in a bath of hot water and the other in a bath of cold water. The figure adjoined obviates the necessity for detailed description. It will be seen that, at regular intervals in the bridge, there are pits, 10 in number, each large enough to contain 3 small vials of copepods in our standard culture medium of protozoa and algae, and that each pit was closed by a large cork stopper through which was passed a thermometer. There was thus obtained a graded series of temperatures which in our

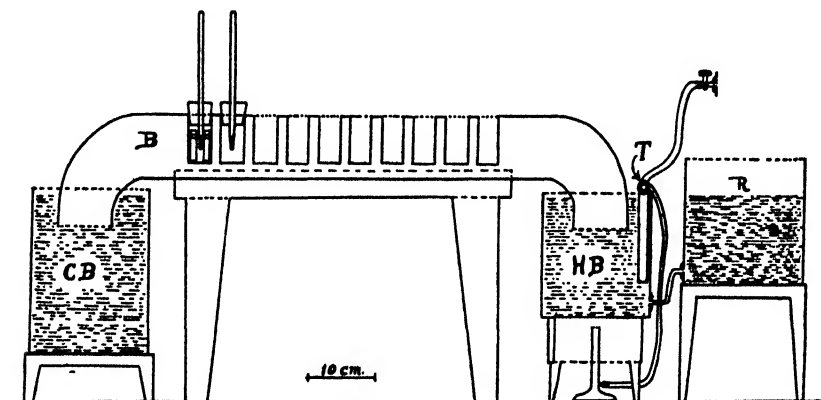


FIG. 1. Serial Temperature apparatus employed in the experiments—the "bloc" of Cardot, Laugier, and Legendre. B, bloc; CB, cold bath; R, reservoir, to which water is added as required by evaporation in hot bath; T, thermo-regulator.

experiments usually ranged from about 27°C. at the cooler end to about 36° at the warmer end. Under the conditions previously mentioned, which made virtually impossible the precise determination of lethal temperatures, a slow fluctuation within the limits of a degree of temperature was not considered objectionable, especially as this could be measurably controlled by frequent observation and by regulation of the flow of gas at the warm end. Greater constancy of the temperature in a given chamber could doubtless have been secured by the addition of thermostatic control at the cool end (a Roux thermoregulator was used at the other end), but it was in no way a defect of the apparatus that such control was not used. This apparatus could readily be



adapted to many biological uses, without sacrifice of principle, by modifications in the way of substantial increase in size, provision of more external insulation, prolongation of the vertical end portions to give greater submergence in the baths, and, if necessary for special purposes, the introduction of double glass windows in the sides of the chambers. Apparatus for similar purposes, involving somewhat the same principles have been described by some others (Livingston and Fawcett, 1920; Williams and Kirkpatrick, 1924; and Zwölfer, 1932).

In our procedure, all copepods were kept at room temperature for a period of a day or more (sometimes for a week) before they were introduced to the temperature chambers. Unless otherwise stated in connection with the several experiments, it may be understood that all were first introduced into the chamber of lowest temperature (26–28°) and then stepped up at intervals of several hours. Usually, then, about two days were required to complete a run. Examination of the copepods was made at each time of transfer and sometimes between transfers, the vials being removed from the chamber for a matter of one or two minutes. When copepods were found to be apparently dead, or entirely dormant, the vials were left out at room temperature for further observation from time to time. In case of resumption of activity by the copepods, they were ordinarily returned after a day to the lowest chamber and then stepped up, to be removed on the reappearance of a condition of positive dormancy. In our records, copepods were recorded as "very lively" when they darted to and fro in the medium, as "active" when they swam about more or less regularly, as "barely alive" when they made only occasional short sleepy leaps, as "practically dormant" when they made no spontaneous movements but would respond to stimuli such as might be given by rolling the vial and causing the animal repeatedly to fall through the water on one of its outstretched antennae or on its caudal setae, as "barely alive" when it would just respond to repeated touches with the point of the needle, to stroking the appendages, etc., and as "dormant" when it would not respond to any such mechanical stimuli. The failure to show activity after a day was for a time considered a sign of death but, as previously mentioned, the only certain criterion of death in the end was internal decomposition.

It will be obvious now that a copepod might go through a series of chambers several times, with the observations continuing for as much as a week before actual death occurred. Such a period of time would naturally allow for the intervention of various complicating influences (including the aging of the copepod!) to such a degree that strict pre-

cision in the determination of lethal temperatures was impracticable. The chief complicating influences might be summarized as: (1) Innate individual idiosyncrasy; (2) diversity of reaction attributable to the previous history of the individual (acquired idiosyncrasy); (3) the time element as permitting the cumulative action of internal disintegrative phenomena; (4) the time element as an acclimatization factor, (5) changes of condition of food supply or of oxygen supply with time, and (6) the possible accumulation of toxic products in the medium. It is not without significance that, after dormancies and revivals, some individuals showed distinctly less and some notably greater tolerance of high temperature.

In spite of the difficulties, some of which are inherent in the conditions of any experimental work with living animals, the experiments may reveal: the approximate temperatures, within about a degree, at which most of the copepods of each species became dormant, the approximate temperatures at which death ensued, the occurrence of a notable degree of diversity of individual tolerances, and the correlation of lethal or dormancy temperatures with some of the previous conditions of life of the animals.

The conditions under which our copepods were reared have been described in another paper (Coker, 1933), to which reference is made. For the sake of brevity, we will hereafter refer to the copepods reared at 7-10°, 11-13°, 14-15°, 18-19°, room temperature, and 28-30°, as 9°, 12°, 15°, 19°, "room," and 29° copepods respectively. It may be remarked that, in general, the copepods reared at the several temperature levels are actually in some measure physically distinct in size and to some extent in proportions (Coker, 1933, and 1934).

For some purposes it might have been preferable to employ large numbers of copepods in each experiment and to have noted the point of temperature or time at which the majority of the copepods became dormant; but the peculiar reactions of copepods to high temperature would have rendered this difficult. Furthermore we were interested in the behaviour of the copepods as individuals. In only two of the many experiments were more copepods used than could be followed individually from the beginning to the end; hence the limited number of individuals employed: 46 (+) *viridis*, 69 (+) *vernalis*, 25 *serrulatus*. The results seem nevertheless clear enough to justify some generalizations.

It must always be kept in mind that in all such experiments, we are watching merely the crude external manifestations of the results of in-

visible and complex internal phenomena. We do not see what takes place within the protoplasm, and how the processes of life there are influenced by all the conditions of genes, environment, and time.

#### OBSERVATIONS

##### *Cyclops viridis* Jurine

The first series of experiments with 9°, 12° 19', room, and 29° copepods all acclimated for about a week at room temperature, indicated merely that the critical temperature was below 34° for all except the 29° copepods, and that for these it was between 35° and 37°. Some representatives of the highest temperature class survived a temperature of 36.7° for several hours.

In other experiments, five 9° copepods, acclimated to room temperature, succumbed at temperatures of 29½° to 31½°. In a special experiment, four 9° females were transferred almost directly from 9° to 26.6°, with no period of acclimation at room temperature. They were then passed rapidly up in seven hours through 26.6°, 27.4°, 29.2°, and 29.5° to 31.5°. All became dormant in course of an hour at the last mentioned temperature. They seemed little less tolerant of high temperatures than copepods of the same class that were allowed a week of acclimation at room temperature (about 21°) and then passed up slowly, in course of a couple of days with stops of several hours at the several intermediate temperatures.

The history of one 9° copepod is, however, of exceptional interest. After passing through two periods of dormancy induced at 31.5°, with overnight revivals at room temperature in each case, it became very inactive at 30° on the third run. It was then put at 32° where it became dormant within two hours. After 6½ hours at this temperature, it was removed in dormant condition to room temperature, where it remained inactive for more than half a day. Within 17 hours it again showed conspicuous activity (3rd revival). Having been put directly at 31° and subjected to a slowly rising temperature up to 32.6°, during a period of 21 hours, the copepod was believed to be dead; however, after removal from the temperature chamber, it revived in course of 24 hours (4th revival). It was now placed directly into the temperature chamber at 34.5°, where it remained active for four hours. When transferred to 36°, it became dormant within 2 hours, and death and decomposition ensued. The only one of the eleven 9° copepods that showed activity at temperatures higher than 31° was one that had

previously revived from four periods of dormancy induced at or below 31.5°, 31.5°, 32°, 32.6°.

Four 12° copepods showed no notably greater tolerance of high temperatures, succumbing at 32.5°.

The 15° copepods employed in the experiments (five females, three males, one 5th-copepodid<sup>3</sup> and five 4th-copepodids) continued to be fairly active at 31.5° and barely active up to 34°, becoming dormant eventually at the latter level or a little below it. On the second run, they became inactive and died at about 34°. The critical temperature seemed to be between 32.5° and 34°.

Room (about 21°) copepods (two females, one 5th copepodid female) became dormant generally between 33° and 34°. One of the females revived from four successive periods of dormancy induced respectively at 33.4°, 31.5°, 34°, 33°. It finally died in course of 18 hours at 34°, the whole experiment with this single animal having endured a little over five days. Another room copepod which had been kept at 9° for two weeks and then at room temperature for a week, showed marked activity at 30°, but became dormant between 33° and 33.6°.

The 29° copepods used in the experiments were from two lines. None of the six copepods of line 11 succumbed at temperatures below 35°, and none survived temperatures of 36.7°. The four copepods in line 111 became dormant at 34°, 35° (only after 14 hours), between 33.4° and 35°, and at 35°, respectively. The last mentioned was the 5th-copepodid and it had remained active for 14 hours at 34°. Three other 29° copepods (line No. 6) survived temperatures of 35° and higher, but died gradually at a temperature slightly above 36°.

It appears then, that the forty-six examples of *viridis*, notwithstanding the diverse hereditary constitutions, all responded to high temperatures in accord with a general rule that the higher the temperature of rearing, the higher the temperature inducing dormancy and death; the critical temperature (35–36°) for 28° copepods being about 4.5° higher than that (30.5–32°) for 9° copepods. A considerable degree of individual variation in response was shown, but not enough to obscure the rule so far as such a rule could be derived from the number of copepods employed.

Most of the copepods showed the capacity of becoming dormant at high temperatures, of remaining so after return to room temperature, for periods of hours to nearly a full day, at least, and of eventual revival and

<sup>3</sup> It may be recalled that in the life history of a copepod, there are six (or five) naupliar instars and six copepodid instars; the 5th-copepodid is, then, the last immature instar.

resumption of apparently normal activity. While dormant, the copepods are, to all appearances, dead, except that they do not ordinarily assume the notably stretched condition usually characteristic of copepods that have died a natural death. The condition of dormancy may be repeated more than once for the same copepod. In several cases the successive periods of dormancy came at approximately the same temperature each time; in a few cases, copepods succumbed at lower temperatures after a period of dormancy; one 9° copepod was remarkable in that, after passing through four periods of dormancy in course of a week induced at approximately the same temperatures (31.5°, 31.5°, 32°, and 31°), it subsequently endured with activity for 4 hours a temperature of 34.5° (to which it had been passed almost immediately from room temperature).

Apparently the lethal temperature was only a degree or two higher than the dormancy temperature, which does not encourage the thought that the phenomenon of dormancy as displayed in these experiments has any notable protective significance.

These copepods, although all reared under known conditions were a random lot as regards heredity, copepods of four lines being employed; this was not the case with the species next considered.

#### *Cyclops vernalis* Fischer

All copepods were the descendants of one female mated in the wild. It had the form of *robustus*, but its systematic position is discussed in another place (Coker, 1934a).

In one series of experiments 9°, 15°, and 29° copepods, after acclimation for a week at room temperature, were run rapidly up through the temperature series, being advanced through five levels in six hours, from 28.2° to 36°. The four 9° copepods were seemingly dead at 32.6–33°. The six 15° copepods, lively at that temperature, succumbed at 34.6–35°, while the one 29° female became dormant only at 36°. The three containers were then removed from the temperature chamber. The 29° copepod revived over night, but the others did not.

A single 12° copepod became dormant at 31°, but revived at the same temperature; it died in a few hours when the temperature was raised to 31.4°.

In different experiments four females and twenty-two males, reared at 15°, survived temperatures rising during 1½ hours from 31.5° to 32.3°, but the last mentioned temperature was apparently injurious. They were relatively inactive and yielded to temperatures above 33.5°.

Four of the males revived within a few hours at room temperature, and were placed back directly at a temperature of 32.7°. Two succumbed, but the other two had an exceptional history. One of them became dormant, but revived after the whole lot were passed up to 34.9°, and there remained active continuously; the two continued active in the end chamber at 36°, and even after the temperature was raised to 36.8°. One of them continued to show activity after 20 hours at temperatures of about 36°, while the other survived for 24 hours, to die finally at 36.4-37°. It is remarkable that after all the copepods of the lot had once succumbed on exposure to temperature of 32.7°, two revived effectively to endure higher temperatures for about a day and a half, including nearly one full day at about 36°.

One 19° adult female, and a lot of 3rd-copepodids of the same temperature class succumbed at temperatures of about 34°. Another 19° female survived six hours at about 34° and three hours at 35½° but died during the night at 36-36.5°. The 4th-copepodid of this class survived much higher temperatures, some dying at 37°, although two survived several hours at 38-38.6°, but only to die while the temperature was rising another degree. In cultural work 4th-copepodids always seemed especially hardy. Some of these ranked in tolerance with adults of the next class.

Copepods of the 29° class (eight females and seven males) survived temperatures up to 37°, two females continuing to be quite active up to 39.6°, but dying in course of the night on a slightly declining temperature.

In summary it may be noted that without exception, the twenty-seven low temperature copepods (11° and 15°) succumbed when first exposed to temperatures a little above 32°, although two 15° males, after behaving as did the others in the first run, had on a later run a remarkable record of tolerance of temperatures up to 36°. The number of 19° adults is too small for conclusion, but the critical temperatures for them were 34° and 36°. The 3rd-copepodids of the same class responded in a similar way, but the 4th-copepodid of this class survived somewhat higher temperatures, two continuing to display some activity up to 38.6°. For 29° copepods, ten adult females, fourteen adult males, and three 5th-copepodid females, 37° was fatal to six females, seven males, and three 5th-copepodids, 38.7° to two females and seven males, and 39.6° or less to two females. The results of all these experiments as far as they go, harmonize with the tentative conclusions drawn from the experiments with *viridis*, that the lethal temperature is generally higher according to the temperature at which the copepod has been reared.

Some little individual diversity in reaction is displayed as might be expected. 4th-copepodids seemed highly resistant relatively to adults and to other instars, which accords with general observation in cultural experience.

*Cyclops serrulatus* Fischer

At the time of these experiments, we had comparatively few examples of this species with known temperature histories: ten 9° copepods (three females, seven males), five 12° copepods (three females, two males), seven 15° copepods (three females, four males), one 19° female, one room female, one 29° female, and a lot of nauplii hatched at 15°. As a rule, none of these survived a temperature of about 34½° on the first run.

Two individuals were of special interest as exemplifying the phenomenon of dormancy and recovery. A 19° copepod with egg-sacs, was run gradually up from 28.5° to 35.6° in the course of 55 hours. The female finally became dormant at 35.7° between the 64th and 66th hour of the experiment. Reviving in a few minutes at room temperature, it was put back into the same chamber where it became dormant again within 3 hours while the temperature of the chamber rose 0.9°. It was only after about 16 hours at room temperature that the copepod began to revive from this dormancy, and it was nearly two days before it seemed normally active. Six days after it was last removed from the temperature chamber, it was reintroduced and became dormant after exposure to a temperature of 34°. A day later at room temperature the copepod was normally active. It passed through three periods of dormancy without apparent permanent injury and required more than a day for recovery from one of the dormancies. The eggs in the sacs carried by the female at the beginning of the experiment hatched at temperatures of 30.7–32.5°, but the nauplii did not endure long a temperature of 35.6°.

A case of notable interest was a 9° female, which had become dormant at about 33.5–34.7° on the first run, had revived at room temperature and had become dormant again on the second run at as low a temperature as 27°. From this second dormancy it gave no sign of recovery at the end of 24 hours and was therefore pronounced dead and set aside. Two days later, however, this female was found to be alive, and, while still in the same vial with eight or nine dead copepods, it lived to produce several batches of fertile eggs in the course of weeks. As we have previously indicated, decomposition seemed to be the only positive criterion of death.

Experiments with *serrulatus* show that copepods of this species have the capacity of becoming dormant at high temperatures, of remaining so for a considerable period of time, and of making ultimately an apparently complete recovery. In these experiments, dormancy occurred at about 34–35° without marked gradation with respect to temperature of rearing, although there seemed to be a small differential of tolerance in favor of the copepods reared at high temperature.

#### CONCLUSIONS AND DISCUSSION

Of the species used in these experiments (*Cyclops viridis* Jurine, *C. vernalis* Fischer, and *C. serrulatus* Fischer), *vernalis* was the most tolerant of high temperatures, *viridis* only a little less so; *serrulatus* seemed less tolerant, but at the time of the experiments, practically no "high temperature" copepods of this species were available for test.

With *vernalis* and *viridis*, tolerance showed correlation with the temperatures at which the copepods had been reared. Although, with *vernalis* the correlation was not observable as between 9° and 12° copepods, it was apparent when these were compared with 15° copepods and quite obvious when 9°, 12°, and 15° animals were compared with 19° or 29° copepods; 29° copepods endured temperatures 6–8° higher than 9° animals. With *viridis* the correlation, although naturally not very notable between 9°, 12°, and 15° animals, was rather obvious when 15° and room copepods were compared, and most conspicuous when 29° animals were compared with copepods reared at lower temperatures; the lethal temperature for 29° copepods was as much as 4.5–6° higher than for 9° copepods. The fact that little or no distinction was noted between the lethal (or dormancy) temperatures for copepods of the lower temperature classes, 9°, 12°, 15°, does not mean necessarily that there are no differentials in toleration among such copepods. For temperature classes so near together, differences conforming to expectancy (based on a differential of about 6° between 9° and 29° classes) would be small and easily obscured by individual variation. Possibly differences of toleration between proximate classes could be revealed by the use of larger numbers of animals or by a different technique. It is possible too, that, somewhere between 15° and 20° there is a critical temperature, and that copepods reared at temperatures above that level are decidedly more tolerant of high temperatures than are those reared at temperatures below it, but the evidence is quite inadequate for conclusion.

While, on the whole, males of *vernalis* and *viridis* seemed less tolerant of high temperatures than did females, the differences were not notable.



The copepods of all three species showed the capacity for a type of dormancy that would persist for hours after return to lower temperatures and a further capacity for recovery and resumption of activity at lower temperatures. Some of the animals became dormant at high temperatures and revived at lower temperature several times (up to four) in course of a week. After revival from dormancy, some copepods showed less, some greater tolerance on a second exposure to high temperature; in general, however, dormancy occurred on successive runs at approximately the same level of temperature. One example of *viridis* and two of *vernalis* displayed a notably high degree of tolerance, the first after 4 periods of dormancy at ordinary dormancy temperature for the class, the latter after one period of dormancy at such a temperature. One *serrulatus*, after the second dormancy, formed several successive sacs of fertile eggs.

Retaining the copepods at an intermediate temperature for a week had no material effect in diminishing the susceptibility of 9° copepods or of increasing that of 29° copepods. Copepods (*viridis*), transferred almost directly from the refrigerator to the high temperature chambers and passed up with periods of about an hour per chamber, showed only slightly more susceptibility than those allowed a week for adjustment to intermediate temperatures and given several hours for supplemental adjustments at the several stages of higher temperatures. The differences of susceptibility do not seem to be the reflection of acclimation in the usual sense of the word—that is to say, the differences of susceptibility are evidently based upon internal physical differences arising from the conditions of development, differences not capable of being smoothed out by such internal adjustments as are effectible in course of a week—no short period in the life of a copepod.

We have found very little in the literature of copepods relating to the special subjects of this paper. Walter (1922), speaking of the extremes of temperature tolerable for *viridis*, remarks that they do not withstand freezing and that they endure temperatures up to 33° and “fallen denn für kurze Zeit in ein Warmstarre und gehen ein.” The “Warmstarre” is apparently what we have recognized as a condition of dormancy. Legendre (1930) reported that for the marine copepod, *Harpacticus fulvus*, a temperature of 36° was fatal in normal or super-saline water, but that 33° was fatal in water of very low density (S. G. 1.006).

Russell (1928, 1932) seems to have been the only writer who has suggested a possible physiological difference in copepods that have developed under different conditions of temperature. His suggestion

was based, not upon experimental work, but upon studies of *Calanus finmarchicus* in collections from the sea, and he speaks of response to light rather than to temperature. There is a certain parallelism between the results of his observations of the sizes and distribution of a marine copepod and the results of our experiments with a freshwater copepod, and we may question if the physiological difference that he suspects may not be with reference to temperature rather than to light. He says (1928):

"It is a striking fact that, when the brood of small [summer-bred] adults begins to predominate in the collections in July, the change appears in the behavior of the *Calanus* and they move nearer the surface. The suggestion at once presents itself that this summer brood may be physiologically different from the brood of large individuals which precedes them in the spring. While the brood of large *Calanus* prefer a somewhat lower intensity of light and live deep in the water, gradually going deeper as the strength of the light increases with the season, the smaller summer brood perhaps prefers a higher intensity of light and lives considerably nearer the surface."

At any rate the facts of distribution that Russell adduces give ground for belief in physiological peculiarities associated with conditions of temperature prevailing during development.

#### *Rate of development in relation to temperature*

It is well known in a general way that copepods develop more rapidly at high than at low temperatures, other conditions being equally favorable (Dietrich, 1915; Walter, 1922; Manfredi, 1923; Roy, 1932); but food-supply, and doubtless other conditions as well, play such a significant part in the control of rate of development, that it would be difficult to fix a schedule corresponding to particular temperatures. We have previously (1933) cited experiments in which, by starvation, the period of development of *vernalis* was prolonged to 5 or 6 times the period considered normal or usual for the temperature. Perhaps the term "normal" is not properly applicable to rate of development. Doubtless, there is a maximum rate for each temperature level, and possibly there is also a minimum rate. That is to say, there may be limits to the period of time that a copepod can remain in a given instar without molting or death;<sup>4</sup> we do not know how long a copepod may continue in a given

<sup>4</sup> Unlike most animals, even such nearly related ones as the cladocera or the decapods, copepods attain sexual maturity only after a fixed number of molts

stage while supplied with food sufficient to sustain life but not sufficient in amount or in kind to permit of the growth necessary to enable the molt to the next stage of development—certainly *viridis*, at room temperature, may remain in the 4th copepod stage for only about a day or for many weeks: can a copepod die of old age in a youthful stage of development? We know of no records to better or to equal ours for complete life cycles (from egg to egg) of *vernalis* (*americanus*) at Chapel Hill, N. C., in 7 days at room temperature; but to call such a rate of

TABLE I  
APPROXIMATE PERIODS OF DEVELOPMENT IN DAYS FOR THREE SPECIES OF  
COPEPODS AT DIFFERENT TEMPERATURES

TEMPER- ATURES	VERNALIS			SERRULATUS			VIRIDIS	
	From nauplius to maturity		Complete cycle, egg to egg	From nauplius to maturity		Complete cycle, egg to egg	From nauplius to maturity	
	♂	♀		♂	♀		♂	♀
°C.								
7-10	44	50	57	35	40—	44	78	73-105
11-13	19	22	28	25	27	36—	37-60	67-98+
14-15	11	12	17	14—	14	19	21+	25-53
18-19	9	10	14	9	10	14	27	31
20-23	7	8	11	8	9	12	13-42	14-52
28-30	5-6	7	14*	7—	7	*	9-17+	10-42+

\* Mating and sac-formation seem usually to be delayed at temperatures above 28°.

development normal would be to make the great majority of the copepods of the species abnormal. A 10 or 11 day period was more common, but we have little other reason for calling that a normal period.

In table I there are given for each of the three species and for several temperature levels, the periods that in our experience may reasonably be expected to suffice for development from nauplius to adult and for complete cycles from egg to egg for both sexes, assuming the cultures to be well-fed. The periods are not minima; we have had somewhat shorter periods in most of the classes. For *viridis* the periods are indicated very broadly, since the species behaved in our cultures with great irregularity—less so after we added plant food to the protozoan

and then cease molting and growth. If there is a variation of even one in the number of instars preceding maturity, within the species, it has not been established (although there has been some difference of opinion as to whether *Cyclops* have 11 or 12 instars in all).

culture medium and less so in mass than in individual cultures; at that, our records seem to be as good as those of Walter (1922), who reported for *viridis* that development required 3-4 weeks at temperatures of 25-30° or several months at low temperatures. The times required for complete cycles from egg to egg are not indicated for *viridis*; at best with the other species, the completion of the cycle depends upon the contingency of mating.

The figures are useful merely to convey a general idea of the influence of temperature on rate of development and possibly to be of use to other breeders of copepods. Even with ample allowance for unavoidable inaccuracy, it must be obvious that the speeding up of development with rise of temperature becomes less and less notable as we ascend the scale of temperature. Thus, with *vernalis*, a rise of about 7° from the lowest class to the third class (14-15°) reduces the period of development by 60-75 percent, while a corresponding rise to about 22° makes a further reduction of 30-40 percent, and a rise to about 29° brings a reduction of only 13 or 14 percent.

#### SUMMARY

The copepods of three species, *Cyclops viridis* Jurine, *vernalis* Fischer, and *serrulatus* Fischer, have the capacity of becoming dormant at high temperatures and of subsequent recovery; the dormancy resembles death, in that the copepods do not respond to stimuli and remain in this condition for hours after return to temperatures far below the critical temperature. After several periods of dormancy, induced by repeated subjection to high temperatures at different times, the copepods may lead apparently normal lives.

The critical temperature for dormancy varied from about 30° to about 38.5°, depending to some extent upon the individual but chiefly upon the temperature under which the copepods had developed. There seems to be a physiological difference between copepods reared at low temperatures and those reared at high temperatures, a difference that persists in spite of adult experiences with reference to temperatures; acclimation of adults to common intermediate temperatures for as much as a week had little effect on relative tolerance for high temperatures. (See conclusions in detail, p. 153.)

Rate of development is to a marked extent a function of temperature, although, to at least an equal extent, it is also a function of food-supply, in quantity (and perhaps in quality)—inference from experiments previously reported. Assuming adequate food-supply, rate of develop-

ment increases as the temperature is raised, as is well known; but the rate of acceleration of development with rise of temperature diminishes very rapidly as we ascend the temperature scale.

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## MATHEMATICA PRAETERMISSA

By ARCHIBALD HENDERSON and JOHN W. LASLEY, JR.

1. *Some critical suggestions in pedagogy and authorship.* In the teaching of undergraduate courses in mathematics and indeed in some of the earlier graduate courses, one finds not infrequently that the text-book constitutes a retardant rather than a lubricant. The author, intent upon some uniform mode of logical development, of which he makes a fetish, neglects the employment of methods and technic which, while constituting a divergence from the preconceived formalism in development, present genuine illumination and simplification. Conversely, there occurs the case of the author who, intent upon furnishing the methods which more quickly yield the desired results, casually "swaps horses in the middle of the stream"—often to the complete and injurious obfuscation of the student. Both methods have what the French call the "defects of their qualities." Rigidity and abruptness alike are out of harmony with the true pedagogical spirit.

Suggestive and helpful to the cultivated teacher is Klein's discipline and program of the treatment of the elementary mathematics from the higher point-of-view.<sup>1</sup> The converse methodology, the treatment of the higher mathematics from the elementary point of view, often yields surprisingly gratifying results, and deserves more intensive cultivation and wider dissemination of results.

A patent and constantly perturbing defect in many standard text-books, even very recent ones, is the glib acceptance of "proof" on the bare evidence of conditions of necessity. Sometimes the necessary condition arrived at is not the only necessary condition, thus magnifying

<sup>1</sup> Felix Klein, *Elementarmathematik vom höheren Standpunkte aus* (3te Auflage, Berlin, Springer. 1925). Consult English translation of Part I of Klein's work with the title "Elementary Mathematics from an Advanced Standpoint—Arithmetic, Algebra, Analysis," by E. R. Hedrick and C. A. Noble (The Macmillan Company, New York, 1932). Compare, in this connection, two papers written to reinforce this point of view: Archibald Henderson, *Observations on Simultaneous Quadratic Equations*, in *American Mathematical Monthly* 35: 337, 1928; and Archibald Henderson and A. W. Hobbs, *The Cubic and Biquadratic Equations—Vieta's Transformation in the Complex Plane*, in *American Mathematical Monthly* 37: 515, 1930.

the error, confusing the student, and incidentally exacerbating the luckless instructor. These defects, as judged by the results, are by no means venial. For they not only evoke in the student's mind disbelief in the trustworthiness of the author: they tend to inspire suspicion regarding the basic validity of all mathematical process. The suggestion that the instructor supply the demonstration of both necessity and sufficiency of conditions is an evasion, not a solution, of the difficulty. Future textbook writers should not idly reject the implications of this paragraph. The older text-books err inexcusably in this respect.

2. *Illustrative theorems and problems.* The problems of the present paper, in the fields of algebra, trigonometry, analytical geometry of the plane and of space, functions of a complex variable, and differential geometry, are chosen as happy and instructive illustrations of the ideas advanced above. They are desiderated illustrations, however well known may be the results, of features neglected or overlooked in text-books: *Mathematica Praetermissa*. They are chosen from the notebook jottings of the authors—*dissecta membra* of pedagogical experience, yet integral to the central objectives of all scientific teaching: thought stimulation, elegant technic, a refreshing air of novelty, accuracy, and completeness. The authors venture to hope that the present paper exemplifies some of the suggestions as to the functions of the *Mathematical Association of America* advanced by Young,<sup>2</sup> and aptly illustrated, in brief papers by Hildebrandt<sup>3</sup> and Franklin.<sup>4</sup>

3. *Simultaneous equations in two variables.* Equations of the type

$$(1) \quad \begin{aligned} x + y &= a, \\ xy &= b \end{aligned}$$

are usually solved by squaring the first equation, subtracting four times the second equation, taking the square roots of the result to obtain  $x - y$ , and combining this difference with the given sum to obtain the separate quantities  $x$  and  $y$ . An alternate method is to solve the first equation for  $y$  in terms of  $x$ , obtaining  $y = a - x$ , and substitute this for  $y$  in the second equation, getting

$$(2) \quad x^2 - ax + b = 0,$$

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<sup>2</sup> J. W. Young, *Functions of the Mathematical Association of America*, *American Mathematical Monthly* 39: 6. 1932.

<sup>3</sup> T. H. Hildebrandt, *Marginal Notes*, *American Mathematical Monthly* 36: 216. 1929.

<sup>4</sup> Philip Franklin, *The Geometric Interpretation of Some Formulas of Analytic Geometry*, *American Mathematical Monthly* 40: 143. 1933.



from which  $x$  is obtained. That the same equation holds for  $y$  is assured by the symmetry of the given equations in  $x$  and  $y$ .

It is important to note that this quadratic equation can be obtained at once by means of the relation between the roots and the coefficients. The first equation in (1) merely states that if  $x$  and  $y$  are regarded as the roots of a certain quadratic equation, the sum of the roots is  $a$ . The second equation in (1) states that the product of these roots is  $b$ . The equation is therefore

$$(3) \quad z^2 - az + b = 0,$$

whose roots are just the  $x = h$  and  $y = k$  which satisfy (1). The other solution of (1) is then, from symmetry,  $x = k$  and  $y = h$ .

Although the foregoing method is fairly well known, it is not so apparent that equations of the type

$$(4) \quad \begin{aligned} x - y &= a, \\ xy &= b \end{aligned}$$

can be solved by the same technic. Upon changing signs in the second equation in (4), we can write

$$(5) \quad \begin{aligned} x + (-y) &= a, \\ x(-y) &= -b. \end{aligned}$$

If then  $x$  and  $-y$  be regarded as roots of a quadratic equation, we have, upon using the relation between the roots and the coefficients,

$$(6) \quad z^2 - az - b = 0,$$

from whose solutions  $x = h$  and  $-y = k$ , we obtain the solutions  $x = h$  and  $y = -k$  of (4). In this case the other solution of (4) is, of course,  $x = k$  and  $y = -h$ .

Thus, given the equations

$$(7) \quad \begin{aligned} x - y &= -1, \\ xy &= 6, \end{aligned}$$

we have the equivalent pair of equations

$$(8) \quad \begin{aligned} x + (-y) &= -1, \\ x(-y) &= -6, \end{aligned}$$

whose solutions  $x$  and  $-y$  are solutions of the quadratic equation

$$(9) \quad z^2 + z - 6 = 0.$$

Solving (9) we have  $x = 2$  and  $-y = -3$ , from which  $x = 2$  and  $y = 3$ , the latter constituting a solution of (7). Of course, the other solution  $x = -3$  and  $-y = 2$ , of (9) leads to the other solution  $x = -3$  and  $y = -2$  of (7). The lack of symmetry in these results is to be expected and is due to the fact that equations of type (4) do not possess symmetry in  $x$  and  $y$ .

4. *Conditions for the roots of a quartic to be in geometric progression.* This problem is given in a reliable standard, though now outmoded, text-book. The answer is so ridiculously inadequate as to excite surprise and condemnation.<sup>5</sup> This, however, is not an isolated or unusual example of the fatuities of authorship the instructor has to combat. This particular problem, because of unusual interest, is presented here in some detail.

For the quartic

$$(1) \quad x^4 + px^3 + qx^2 + rx + s = 0, \quad (p, q, r, s \neq 0),$$

with the roots chosen in G. P. as

$$\frac{m}{\rho^3}, \quad \frac{m}{\rho}, \quad m\rho, \quad m\rho^3$$

we have

$$(2) \quad m \left( \rho + \frac{1}{\rho} \right) \left( \rho^2 + \frac{1}{\rho^2} \right) = -p,$$

$$(3) \quad m^2 \left( \rho^2 + \frac{1}{\rho^2} \right) \left\{ \left( \rho^2 + \frac{1}{\rho^2} \right) + 1 \right\} = q,$$

$$(4) \quad m^3 \left( \rho + \frac{1}{\rho} \right) \left( \rho^2 + \frac{1}{\rho^2} \right) = r,$$

$$(5) \quad m^4 = s.$$

By combining (2), (4), and (5), we have by inspection one necessary condition on the coefficients:

$$(A) \quad p^2s - r^2 = 0.$$

---

<sup>5</sup> Burnside and Panton, *Theory of Equations*, 3d Edition (Longmans, Green and Co., London. 1892), exercises 22 and 23, page 41.

Although in the text-book cited above, only the condition (A) is given, this is obviously inadequate and misleading, as a numerical illustration will show. A quartic with the four roots  $\alpha = \frac{1}{2}, \beta = 2, \gamma = 1, \delta = 1$  satisfies condition (A); but the roots are not in G. P., although  $\alpha\beta = \gamma\delta$ .<sup>6</sup> Obviously if  $\alpha, \gamma, \delta, \beta$  are in G. P. we must have  $\gamma : \alpha = \delta : \gamma = \beta : \delta$ . Condition (A), in not containing  $g$ , is manifestly inadequate.

Combining (3) and (5), and solving for  $\rho^2 + \frac{1}{\rho^2}$ , we find

$$(6) \quad R = \rho^2 + \frac{1}{\rho^2} = \frac{-\sqrt{s} \pm \sqrt{s + 4q\sqrt{s}}}{2\sqrt{s}}.$$

Combining (4), (5) and (6), we find

$$(7) \quad \left(\rho + \frac{1}{\rho}\right)^2 = \frac{4r^2}{\sqrt{s}(-\sqrt{s} \pm \sqrt{s + 4q\sqrt{s}})^2}.$$

Making use of the identity

$$(I) \quad \rho^2 + \frac{1}{\rho^2} = \left(\rho + \frac{1}{\rho}\right)^2 - 2$$

we find, after reduction,

$$(8) \quad [2r^2 - s^{3/2} - qs] = s^{3/2}(q - s^{1/2})^2(4q + s^{1/2}).$$

From condition (A), setting  $\sqrt{s} = \frac{r}{p}$ , we find

$$(B) \quad r(2p^3 - pq - r)^2 = (pq - r)^2(4pq + r)$$

which may be written either

$$(B') \quad pq^3 - 2q^2r + p^2qr - p^4r + pr^2 = 0$$

or

$$(B'') \quad r(p^4 - p^2q + 2q^2) = p(r^2 + q^3).$$

Substituting  $ps^{\frac{1}{2}}$  for  $r$  in equation (B'') we find

$$(C) \quad s(p^4 - p^2q + 2q^2)^2 = (p^2s + q^3)^2.$$

Hence conditions (A) and (B) are necessary conditions for the roots of the quartic (1) to be in geometrical progression.

<sup>6</sup> Burnside and Panton, l.c.

Otherwise, we have from (2) and (3) and the identity (I)

$$(9) \quad R^3 + 2R^2 + l = 0,$$

and

$$(10) \quad R^2 + R + k = 0,$$

where  $l = -p^3/r$ , and  $k = -pq/r$ . By Sylvester's dialytic method of elimination (Cf. Dickson's First Course in the Theory of Equations, New York, 1922, §112) a necessary and sufficient condition that equations (9) and (10) have a common solution is

$$\begin{vmatrix} 1 & 2 & 0 & l & 0 \\ 0 & 1 & 2 & 0 & l \\ 1 & 1 & k & 0 & 0 \\ 0 & 1 & 1 & k & 0 \\ 0 & 0 & 1 & 1 & k \end{vmatrix} = 0,$$

which readily yields

$$k(k+1)^2 = (k-l)(l+1)$$

and substituting in this equation the values for  $k$  and  $l$  we obtain

$$(B''') \quad q(r-pq)^2 = r(p^2-q)(p^3-r),$$

which is an alternative form of (B) above.

It may be noted that conditions (A) and (B) are satisfied by the relations

$$q = p^2, \quad r = p^3, \quad s = p^4,$$

giving rise to the equation

$$(11) \quad x^4 + px^3 + p^2x^2 + p^3x + p^4 = 0,$$

which, by the transformation  $x = py$ , is seen to be a cyclotomic equation, whose roots are in G. P.

Let us now consider the converse proposition. Take the quartic

$$x^4 + px^3 + qx^2 + rx + s = 0$$

with coefficients satisfying conditions (A) and (B). We shall show that the roots of the quartic can be represented by the expressions  $\alpha, \alpha\lambda, \alpha\lambda^2, \alpha\lambda^3$ , that is, the roots are in G. P.<sup>7</sup>

Since (B) holds, equations (9) and (10) have at least one common root  $R$ . Moreover  $R \neq 0$ , since  $p \neq 0$  in (10), so that  $\lambda \neq -1$  or  $\pm i$ . Hence there exist at least two values (distinct or identical) of  $\lambda (\neq 0)$  satisfying

$$\left(\lambda^2 + \frac{1}{\lambda^2}\right) + \left(\lambda + \frac{1}{\lambda} + 2\right) = \frac{pq}{r},$$

$$\left(\lambda + \frac{1}{\lambda}\right)^2 \left(\lambda + \frac{1}{\lambda} + 2\right) = \frac{p^3}{r}$$

and these two values are reciprocals of each other. Now if we choose  $\alpha$  to satisfy

$$(5') \quad \alpha^2 \lambda^3 = \frac{r}{p}$$

these values of  $\lambda$  will satisfy (3) and the square of (2). Moreover, by the proper choice of the sign of  $\alpha$  in  $\alpha = \pm \sqrt{r/p\lambda^3}$  these values of  $\lambda$  and  $\alpha$  will satisfy (2). Since (2), (3), (5') and (A) imply (2), (3), (4) and (5), the roots of the quartic will be  $\alpha, \alpha\lambda, \alpha\lambda^2, \alpha\lambda^3$ , which are in G. P.

The conditions in (A), (B) and (C) may also be shown to hold, even if  $r = 0$ . In this event, four cases will arise:

$$\text{a) } \alpha = 0, \quad \text{b) } \lambda = 0, \quad \text{c) } \lambda = -1, \quad \text{d) } \lambda = \pm i.$$

In case a)  $p = q = s = 0$  which satisfy (A), (B) and (C).

In case b)  $q = r = s = 0, p = -\alpha$  and again (A), (B), (C) hold.

In case c)  $p = r = 0, q = -2\alpha^2, s = \alpha^4$ , so (A) and (B) hold; and (C) which becomes  $\alpha^4(8\alpha^4)^2 = (-8\alpha^6)^2$  is also satisfied.

In case d)  $p = q = 0, s = -\alpha^4$ , so that (A), (B), and (C) hold. Hence in all cases, where  $r = 0$ , (A), (B), and (C) are necessary conditions that the quartic (1) have its roots in G. P.

Conversely, let (A), (B) and (C) hold. If  $r \neq 0$ , (A) and (B) are themselves sufficient conditions that the quartic have its roots in G. P. Let us suppose then that  $r = 0$ . From (A), (B) and (C) we derive  $p^2s = 0$  and  $pq^3 = 0$ . Consequently, either  $p = 0$  or  $q = s = 0$ . If

<sup>7</sup> For convenience in notation  $\alpha$  and  $\lambda$  are assigned rôles corresponding to  $\frac{m}{\rho^2}$  and  $\rho^2$  respectively in the preceding discussion. Equations in  $\alpha$  and  $\lambda$  corresponding to (2), (3), (4), and (5) are referred to in the sequel.

$p = 0$ , (C) becomes  $4s = q^2$ . Hence  $q = 0$  or,  $s = \frac{1}{4}q^2$ . If  $q = 0$ , we have  $p = q = r = 0$ ,  $\lambda = \pm i$  and the quartic becomes  $x^4 + s = 0$ , whose roots are the four fourth roots of  $-s$ , which are in G. P., with the ratio  $\lambda = \pm i$ .

If  $s = \frac{1}{4}q^2$ , the quartic becomes

$$x^4 + qx^2 + \frac{1}{4}q^2 = 0,$$

whose roots are

$$\sqrt{\frac{q}{2}}, \quad -\sqrt{\frac{q}{2}}, \quad \sqrt{\frac{q}{2}}, \quad -\sqrt{\frac{q}{2}},$$

which is a G. P., with ratio  $-1$ .

Finally, if  $q = s = 0$ , the quartic becomes  $x^4 + px^3 = 0$  with roots  $-p, 0, 0, 0$ , which is a G. P., with ratio 0.

Thus we have established the following<sup>8</sup>

**THEOREM:** *The roots of the quartic*

$$x^4 + px^3 + qx^2 + rx + s = 0$$

*will be in Geometrical Progression if, and only if, the following conditions hold*

$$(A) \quad r^2 = p^2s,$$

$$(B) \quad r(p^4 - p^2q + 2q^2) = p(r^2 + q^2).$$

5. *The law of tangents for the plane triangle.* There are numerous geometric proofs of the Law of Tangents for the plane triangle. Many of these require auxiliary constructions of somewhat elaborate character. In developments of trigonometry in which the sum and difference formulas for angles are given late, or not at all, a geometric proof of this important law is desirable.

It is of interest to observe that a very simple proof of this law is afforded by merely projecting the sides of the triangle upon a bisector of an angle, then projecting the sides upon a perpendicular to this bisector, and dividing one of these results by the other. The results of these projections are the two formulas which usually go under the name of Mollweide's Equations, although there seems little justification for the name. The details follow:

Consider the triangle  $ABC$ , in which for definiteness the angle  $A$  has

<sup>8</sup> For interesting suggestions, the authors are indebted to their colleague Professor Edward T. Browne.

been taken greater than the angle  $B$ . Draw the bisector of the angle  $C$ . Through  $B$  draw a perpendicular to this bisector, meeting it in  $D$ . From  $A$  draw a perpendicular to  $BD$ , meeting it in  $E$ . From  $A$  draw a perpendicular to the bisector, meeting it in  $F$ .

The angle  $CBD$  is the complement of one-half the angle  $C$ , and is therefore  $\frac{A+B}{2}$ .

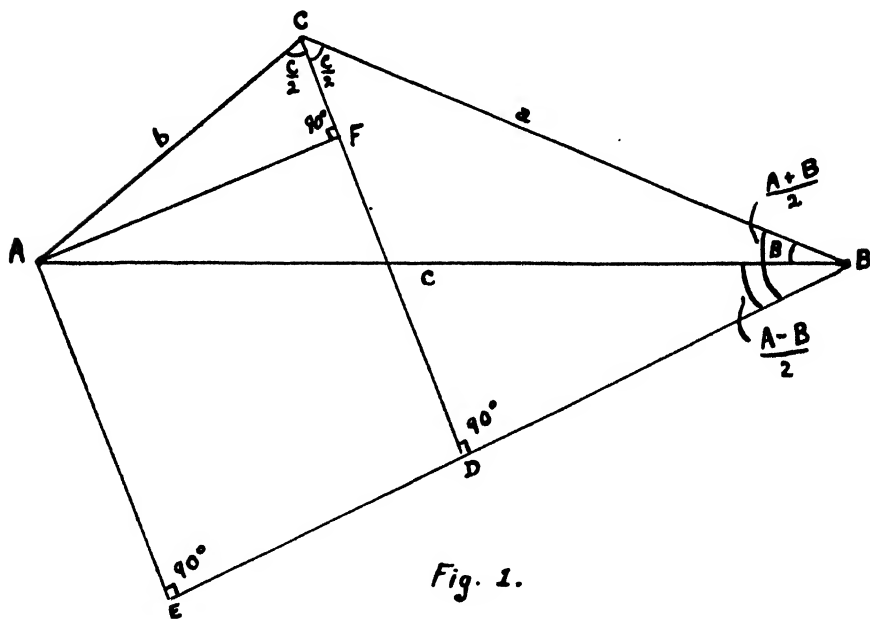


Fig. 1.

The angle  $ABE$  is such that its sum with the angle  $B$  must give  $\frac{A+B}{2}$ , and consequently must be  $\frac{A-B}{2}$ .

By inspection from the figure we have

$$CF + FD = CD,$$

or

$$CF + AE = CD,$$

therefore

$$b \cos \frac{C}{2} + c \sin \frac{A-B}{2} = a \cos \frac{C}{2}$$

that is

$$(1) \quad (a - b) \cos \frac{C}{2} = c \sin \frac{A - B}{2}$$

one of the Mollweide equations.

Again from the figure

$$ED + DB = EB,$$

or

$$AF + DB = EB,$$

therefore,

$$b \sin \frac{C}{2} + a \sin \frac{C}{2} = c \cos \frac{A - B}{2}$$

that is

$$(2) \quad (a + b) \sin \frac{C}{2} = c \cos \frac{A - B}{2},$$

the other Mollweide equation.

If now we divide (1) by (2) we have

$$(3) \quad \frac{a - b}{a + b} \cot \frac{C}{2} = \tan \frac{A - B}{2}$$

or

$$(4) \quad \frac{\tan \frac{A - B}{2}}{\tan \frac{A + B}{2}} = \frac{a - b}{a + b},$$

the usual form of the Law of Tangents.

If angle  $B$  is greater than angle  $A$ , the foregoing proof applies with  $A$  interchanged with  $B$  and  $a$  interchanged with  $b$ . The result will be (4) with these letters interchanged. From this we can obtain (4) again by changing signs on both sides after using the fact that the tangent of the negative of an angle is the negative of the tangent of the angle.

If the angle  $A$  is equal to the angle  $B$ , the triangle is isosceles and is best handled by the principles of right angled triangles. However, both the foregoing method and result are valid, although trivial.



If  $A$  is a right angle, again the method of right triangles is superior, but neither the above method nor the result is vitiated.

6. *Derivation of the equation of the ellipse.* The problem of harmonizing the two usual definitions of the ellipse is always an interesting one. Let us suppose that the definition is that of the locus of points the sum of whose distances from two fixed points is constant, and equal to  $2a$ . Let us proceed to set up the problem in the usual way, denoting the two fixed points by  $F$  and  $F'$ , the typical point on the locus by  $P$ , and the distances  $FP$  and  $F'P$  by  $f$  and  $f'$ , the so-called focal radii. Let us employ cartesian coördinates with  $FF'$  as the  $x$ -axis and the perpendicular bisector of  $FF'$  as  $y$ -axis. In such a system we have the following coördinates of points:  $F(c, 0)$ ,  $F'(-c, 0)$ ,  $P(x, y)$ , where  $F'F = 2c$ . We have at once from the distance formula

$$\begin{aligned} f^2 &= x^2 - 2cx + c^2 + y^2 \\ f'^2 &= x^2 + 2cx + c^2 + y^2, \end{aligned} \quad (1)$$

whence, upon subtracting,

$$f'^2 - f^2 = 4cx. \quad (2)$$

Now by the definition of the curve

$$f' + f = 2a; \quad (3)$$

consequently, upon dividing (2) by (3), we obtain

$$f' - f = \frac{2c}{a}x. \quad (4)$$

If now we combine (3) and (4) we have

$$\begin{aligned} f' &= a + ex \\ f &= a - ex, \end{aligned} \quad (5)$$

where we have written  $e$  for  $c/a$ . We are thus led immediately to the focal radii property.  $\square$   $\square$

Let us now factor out  $e$  on the right of the second equation in (5). We obtain

$$f = e(p - x), \quad (6)$$

in which  $p$  has been written for  $a/e$ .

Now the expression in the parenthesis on the right in (6) represents, except for sign, the perpendicular distance from the line  $x = p$  to the

point  $(x, y)$ . Equation (6) is then merely a statement that points  $P$  on our ellipse are such that the distance  $f$  from the fixed point  $F$  is proportional to the distance from the fixed line  $x - p = 0$ , the proportionality factor being  $e$ , the usual eccentricity. We thus arrive very early at the focus-directrix-eccentricity point of view, and see readily that it follows from the fact that the sum of the focal radii is constant. Of course, the first equation in (5) may be used in similar manner to the above to establish the left hand directrix.

To obtain the cartesian equation of the curve we revert to the second equation in (5), restoring to  $e$  its value  $c/a$ . We have

$$(7) \quad f = a - \frac{c}{a} x.$$

Squaring both sides in (7) and using the first equation in (1) we obtain

$$x^2 - 2cx + c^2 + y^2 = a^2 - 2cx + \frac{c^2}{a^2} x^2,$$

whence

$$\frac{a^2 - c^2}{a^2} x^2 + y^2 = a^2 - c^2.$$

Now  $a^2 - c^2$  is essentially positive, and can be replaced by  $b^2$ , giving

$$\frac{b^2}{a^2} x^2 + y^2 = b^2,$$

from which, upon dividing by  $b^2$ , there results the usual standard form of the ellipse

$$\frac{x^2}{a^2} + \frac{y^2}{b^2} = 1.$$

A similar technic is available for the hyperbola. It seems noteworthy that in neither treatment is the use of a radical necessary.

7. *Conjugate diameters.* Given the coordinates  $(x', y')$  of a point  $P'$  on the ellipse

$$\frac{x^2}{a^2} + \frac{y^2}{b^2} = 1,$$

let us find the coördinates of the ends of the diameter conjugate to the diameter passing through  $P'$ . This is usually done in the text-books by obtaining the equation of the conjugate diameter from its property of

being parallel to the tangent at  $P'$ , and solving this equation together with the equation of the ellipse. The method leads to some awkward algebra.

If instead we write the condition

$$(1) \quad \frac{x'^2}{a^2} + \frac{y'^2}{b^2} = 1$$

in the form

$$\frac{(ay'/b)^2}{a^2} + \frac{(bx'/a)^2}{b^2} = 1,$$

we see at once that not only is the point  $(x', y')$  on the ellipse, but so also are the four points

$$\left( \pm \frac{ay'}{b}, \pm \frac{bx'}{a} \right).$$

The slope of the diameter through  $(x', y')$  is  $m = y'/x'$ . The slope of the diameter through  $\left( -\frac{ay'}{b}, \frac{bx'}{a} \right)$  is

$$m' = \frac{bx'}{a} \bigg/ \left( -\frac{ay'}{b} \right) = -\frac{b^2 x'}{a^2 y'}.$$

The product of these two slopes is:

$$mm' = \frac{y'}{x'} \left( -\frac{b^2 x'}{a^2 y'} \right) = -\frac{b^2}{a^2}.$$

Of course the point  $\left( \frac{ay'}{b}, -\frac{bx'}{a} \right)$  would serve equally well for the foregoing purpose, locating just as surely the conjugate diameter by means of its opposite end. Neither of the remaining two points of the above mentioned four points, however, would serve, since the diameter which they determine has a slope whose product with the slope of the given diameter through  $P'$  is  $b^2/a^2$ . This is therefore not the diameter in question. Since there is only one diameter conjugate to a given diameter, our problem is solved.

The above method is equally applicable to the hyperbola.

8. *Method of rectangular coördinates for drawing the product and quotient of two complex quantities.* \* It is the uniform practice of text-book writers to derive the rules for obtaining the points representing the sum and difference (two of the latter) of two complex numbers by means of rectangu-

lar coördinates; but to derive the rules for obtaining their product and quotient (two of the latter) by means of polar coördinates. This abrupt change in the type of coördinates without any explanation is confusing to the student; and is not clarified by the justification of speed in deriving the result. In this section are set forth methods for locating the points representing the product and the quotient of two complex numbers by

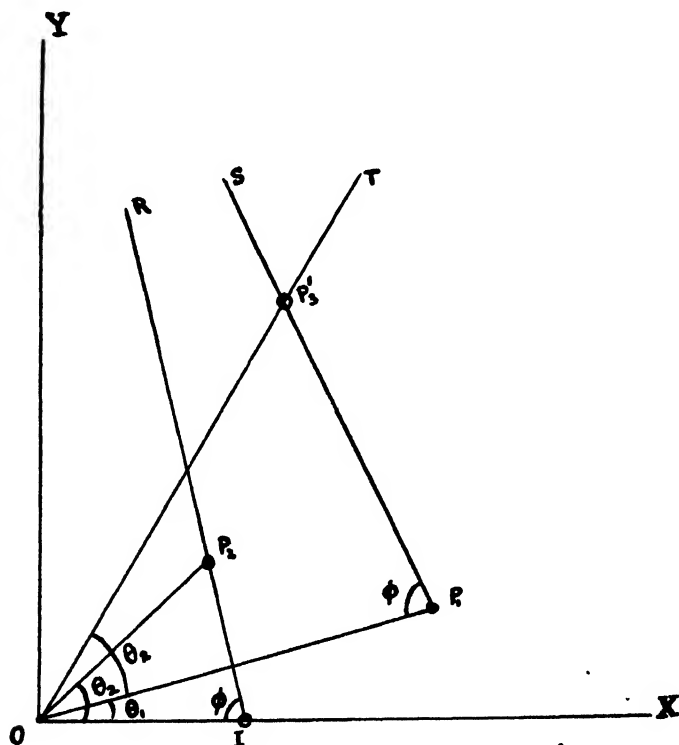


Fig. 2.

means of rectangular coördinates. In the methods herein employed the triangles paired for similarity are not those employed in the conventional treatment of the text-books, although in each case the complete geometrical configurations embracing both methods is the same.

(a) Given  $z_1 = a_1 + b_1i$ ,  $z_2 = a_2 + b_2i$ , two complex quantities represented by the points  $P_1$ ,  $P_2$ , of Fig. 2, where  $\angle XOP_1 \equiv \theta_1$  and  $\angle XOP_2 \equiv \theta_2$ .

To find the product

$$z_1 z_2 = (a_1 a_2 - b_1 b_2) + (a_1 b_2 + a_2 b_1) i$$

represented by the point  $P_3$ .

Extend the line through the points  $I$  (1, 0) and  $P_2$  to any arbitrary point  $R$ . Join the origin to  $P_2$ . Lay off the lines  $P_1 S$  and  $OT$  making with  $OP_1$  angles equal to  $\angle OIP_2 = \phi$ ,  $\angle IOP_2 = \theta_2$ , respectively. These lines meet in a point  $P'_3$  which we shall show is the desired point  $P_3$  above, and represents the product  $z_1 z_2$ . This follows from the direct similarity of the triangles  $OIP_2$  and  $OP_1 P'_3$ . Calculation immediately gives:

$$\begin{aligned} OI &= 1, & IP_2 &= \sqrt{(1 - a_2)^2 + b_2^2}, & OP_2 &= \sqrt{a_2^2 + b_2^2}, \\ OP_1 &= \sqrt{a_1^2 + b_1^2}, & P_1 P'_3 &= \sqrt{a_1^2 + b_1^2} \sqrt{(1 - a_2)^2 + b_2^2}, \\ OP'_3 &= \sqrt{a_1^2 + b_1^2} \sqrt{a_2^2 + b_2^2}, \end{aligned}$$

since the sides of these similar triangles are proportional.

Furthermore,

$$\begin{aligned} \cos XOP'_3 &= \cos(\theta_1 + \theta_2) = \cos \theta_1 \cos \theta_2 - \sin \theta_1 \sin \theta_2 \\ &= \frac{a_1}{\sqrt{a_1^2 + b_1^2}} \cdot \frac{a_2}{\sqrt{a_2^2 + b_2^2}} - \frac{b_1}{\sqrt{a_1^2 + b_1^2}} \cdot \frac{b_2}{\sqrt{a_2^2 + b_2^2}} \\ &= \frac{a_1 a_2 - b_1 b_2}{\sqrt{a_1^2 + b_1^2} \sqrt{a_2^2 + b_2^2}}. \end{aligned}$$

Now the abscissa of the point  $P'_3$  is given by

$$x_3 = OP'_3 \cos XOP'_3 = a_1 a_2 - b_1 b_2.$$

Similarly we have

$$\sin XOP'_3 = \frac{a_1 b_2 + a_2 b_1}{\sqrt{a_1^2 + b_1^2} \sqrt{a_2^2 + b_2^2}},$$

which gives us for the ordinate of the point  $P'_3$

$$y_3 = OP'_3 \sin XOP'_3 = a_1 b_2 + a_2 b_1.$$

But these are just the required abscissa and ordinate of the point  $P_3$ . We have thus shown that the foregoing construction leads us to the product  $z_1 z_2$ .

This method of construction formulated above holds if we interchange

the points  $P_1$  and  $P_2$ , since the operation of multiplication is commutative.

(b) To find the quotient

$$\frac{z_1}{z_2} = \frac{a_1 + b_1 i}{a_2 + b_2 i} = \left( \frac{a_1 a_2 + b_1 b_2}{a_2^2 + b_2^2} \right) + \left( \frac{a_2 b_1 - a_1 b_2}{a_2^2 + b_2^2} \right) i,$$

represented by the point  $Q_{12}$ . See Fig. 3.

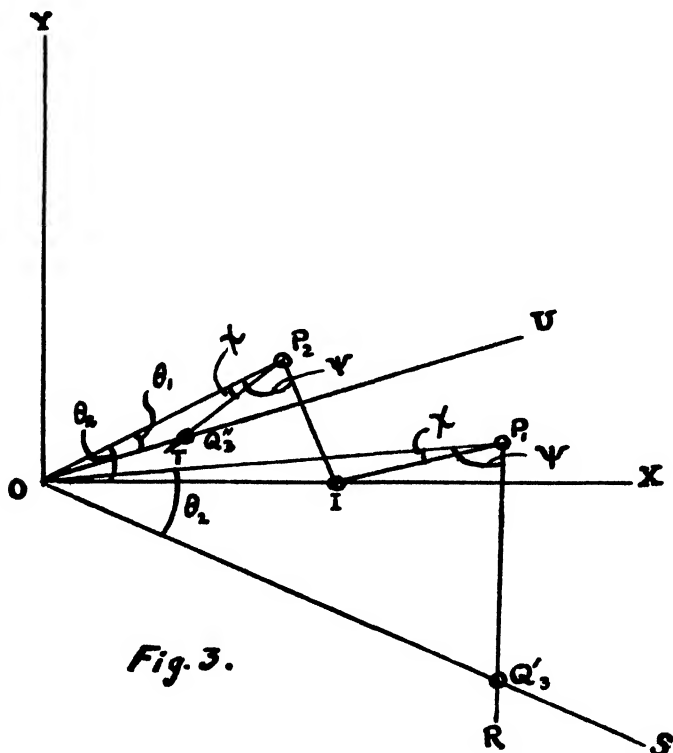


Fig. 3.

Draw  $OP_2$ ,  $IP_2$  and lay off from  $OP_1$ , each measured in the sense of its equal, the angles  $OP_1R$ ,  $P_1OS$  equal respectively to the angles  $OP_2I$ ,  $P_2OI$ . The lines  $P_1R$ ,  $OS$  meet in the point  $Q'_2$ , which represents the required quotient  $\frac{z_1}{z_2}$ .

The proof, as in the case of the product, follows from the direct similarity of the triangles  $OP_2I$  and  $OP_1Q'_2$ . Calculation gives

$$OI = 1, \quad OP_2 = \sqrt{a_2^2 + b_2^2}, \quad IP_2 = \sqrt{(1 - a_2)^2 + b_2^2},$$

$$OQ'_3 = \frac{\sqrt{a_1^2 + b_1^2}}{\sqrt{a_2^2 + b_2^2}}, \quad OP_1 = \sqrt{a_1^2 + b_1^2} = \frac{\sqrt{a_1^2 + b_1^2}}{\sqrt{a_2^2 + b_2^2}} \cdot \sqrt{a_2^2 + b_2^2},$$

$$P_1Q'_3 = \frac{\sqrt{a_1^2 + b_1^2}}{\sqrt{a_2^2 + b_2^2}} \cdot \sqrt{(1 - a_2)^2 + b_2^2},$$

since the sides of these similar triangles are proportional.

Furthermore,

$$\begin{aligned} \cos XOQ'_3 &= \cos (\theta_1 - \theta_2) = \cos \theta_1 \cos \theta_2 + \sin \theta_1 \sin \theta_2 \\ &= \frac{a_1}{\sqrt{a_1^2 + b_1^2}} \cdot \frac{a_2}{\sqrt{a_2^2 + b_2^2}} + \frac{b_1}{\sqrt{a_1^2 + b_1^2}} \cdot \frac{b_2}{\sqrt{a_2^2 + b_2^2}} \\ &= \frac{a_1 a_2 + b_1 b_2}{\sqrt{a_1^2 + b_1^2} \sqrt{a_2^2 + b_2^2}}. \end{aligned}$$

Now the abscissa of the point  $Q'_3$  is given by

$$x'_3 = OQ'_3 \cos XOQ'_3 = \frac{a_1 b_2 + a_2 b_1}{a_2^2 + b_2^2}.$$

Similarly we have

$$\sin XOQ'_3 = \frac{a_2 b_1 - a_1 b_2}{\sqrt{a_1^2 + b_1^2} \sqrt{a_2^2 + b_2^2}},$$

which gives us for the ordinate of  $Q'_3$

$$y'_3 = OQ'_3 \sin XOQ'_3 = \frac{a_2 b_1 - a_1 b_2}{a_2^2 + b_2^2}.$$

But these are just the required abscissa and ordinate of the point  $Q_{12}$ . We have thus shown that the foregoing construction leads us to the quotient  $\frac{z_1}{z_2}$ .

(c) To find the quotient

$$\frac{z_2}{z_1} = \frac{a_2 + b_2 i}{a_1 + b_1 i} = \left( \frac{a_1 a_2 + b_1 b_2}{a_1^2 + b_1^2} \right) + \left( \frac{a_1 b_2 - a_2 b_1}{a_1^2 + b_1^2} \right) i.$$

Lay off from  $OP_2$ , each measured in the same sense as its equal, the angles  $OP_2 T$  and  $P_2 OU$  equal respectively to the angles  $OP_1 I$ ,  $P_1 OI$ .

These lines  $P_2 T$ ,  $OU$  meet in the point  $Q''_3 = \frac{z_2}{z_1}$ . As formerly, the proof

follows from the direct similarity of the triangles  $OP_1I$  and  $OP_2Q_3''$ . By computation we have

$$\begin{aligned}OI &= 1, & OP_1 &= \sqrt{a_1^2 + b_1^2}, & IP_1 &= \sqrt{(1 - a_1)^2 + b_1^2}, \\ OQ_3'' &= \frac{\sqrt{a_2^2 + b_2^2}}{\sqrt{a_1^2 + b_1^2}}, & OP_2 &= \sqrt{a_2^2 + b_2^2} = \frac{\sqrt{a_2^2 + b_2^2}}{\sqrt{a_1^2 + b_1^2}} \cdot \sqrt{a_1^2 + b_1^2}, \\ P_2Q_3'' &= \frac{\sqrt{a_2^2 + b_2^2}}{\sqrt{a_1^2 + b_1^2}} \sqrt{(1 - a_1)^2 + b_1^2},\end{aligned}$$

since the sides of these similar triangles are proportional.

Furthermore, in the manner above, we have

$$\cos XOQ_3'' = \frac{a_1 a_2 + b_1 b_2}{\sqrt{a_1^2 + b_1^2} \sqrt{a_2^2 + b_2^2}}.$$

Now the abscissa of the point  $Q_3''$  is given by

$$x_3'' = OQ_3'' \cos XOQ_3'' = \frac{a_1 a_2 + b_1 b_2}{a_1^2 + b_1^2}.$$

Similarly we have

$$\sin XOQ_3'' = \frac{a_1 b_2 - a_2 b_1}{\sqrt{a_1^2 + b_1^2} \sqrt{a_2^2 + b_2^2}},$$

which gives us for the ordinate of  $Q_3''$

$$y_3'' = OQ_3'' \sin XOQ_3'' = \frac{a_1 b_2 - a_2 b_1}{a_1^2 + b_1^2}.$$

But these are just the abscissa and ordinate of the required point. We have thus shown that the foregoing construction leads to the quotient  $\frac{z_2}{z_1}$ .

Clearly a rule formulated in case (b) makes unnecessary case (c). Obviously the mere interchange of the points  $P_1$  and  $P_2$  does not, as in case (a), lead to the same point, since the operation of division is not commutative. As a check,  $Q_3''$  is found by reflecting  $Q_3'$  in the unit-circle and then in the axis of reals, or in the reverse order.

9. A necessary and sufficient condition for the intersection of two lines in space. To find the necessary condition for the lines

$$(1) \quad \frac{x - x_1}{l_1} = \frac{y - y_1}{m_1} = \frac{z - z_1}{n_1} = \rho_1,$$

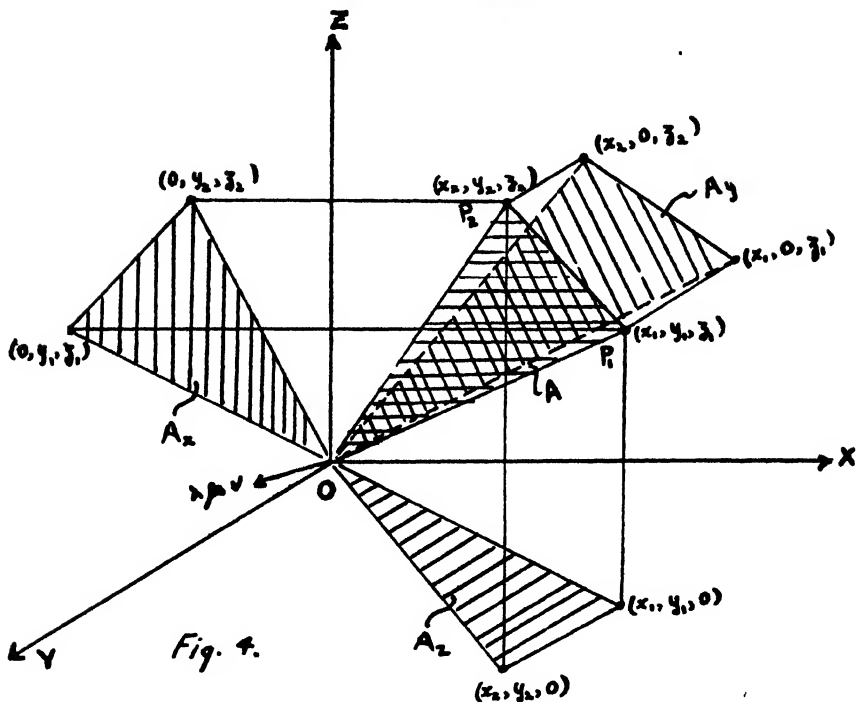


and

$$(2) \quad \frac{x - x_2}{l_2} = \frac{y - y_2}{m_2} = \frac{z - z_2}{n_2} = \rho_2$$

to intersect, we readily derive, in any one of several ways,

$$(3) \quad \begin{vmatrix} x_1 - x_2 & l_1 & l_2 \\ y_1 - y_2 & m_1 & m_2 \\ z_1 - z_2 & n_1 & n_2 \end{vmatrix} = 0.$$



In the ordinary text-books the sufficiency of this condition is accepted without further parley. It is, however, not difficult to prove the sufficiency of this condition, since we may easily derive the following formula for the common perpendicular,  $p$ , to the two lines:

$$p = \pm \begin{vmatrix} x_1 - x_2 & l_1 & l_2 \\ y_1 - y_2 & m_1 & m_2 \\ z_1 - z_2 & n_1 & n_2 \end{vmatrix} \sin \theta :$$

where  $\theta$  (not a multiple of  $\pi$ ) is the angle between the lines. Clearly, if (3) holds,  $p$  is zero, and the lines (1) and (2) intersect.

10. *Geometric proof of Lagrange's identity.* In the algebra of determinants we have the important theorem which goes by the name of Lagrange's Identity. We may state this theorem thus

$$\begin{vmatrix} x_1^2 + y_1^2 + z_1^2 & x_1 x_2 + y_1 y_2 + z_1 z_2 \\ x_1 x_2 + y_1 y_2 + z_1 z_2 & x_2^2 + y_2^2 + z_2^2 \end{vmatrix} = \begin{vmatrix} y_1 & z_1 \\ y_2 & z_2 \end{vmatrix}^2 + \begin{vmatrix} z_1 & x_1 \\ z_2 & x_2 \end{vmatrix}^2 + \begin{vmatrix} x_1 & y_1 \\ x_2 & y_2 \end{vmatrix}^2.$$

We shall outline a geometric proof of the theorem. Consider two distinct points  $P_1 (x_1, y_1, z_1)$  and  $P_2 (x_2, y_2, z_2)$  of space, and the area  $A$  of the triangle formed by these points and the origin of coördinates. Project this area orthogonally on to the reference planes into the areas designated by  $A_x, A_y$  and  $A_z$ , the areas of certain triangles with vertices whose coördinates are indicated in Fig. 4. If  $\lambda, \mu, \nu$  denote the direction cosines of the normal to the plane of the triangle  $OP_1P_2$ . We have from analytic geometry  $A_x = \lambda A, A_y = \mu A, A_z = \nu A$ . But  $\lambda^2 + \mu^2 + \nu^2 = 1$ . Therefore  $A_x^2 + A_y^2 + A_z^2 = A^2$ . We can write

$$(1) \quad 4A^2 = 4A_x^2 + 4A_y^2 + 4A_z^2.$$

In triangle  $OP_1P_2$  we have

$$2A = OP_1 \cdot OP_2 \cdot \sin \theta$$

or

$$(2) \quad 4A^2 = \overline{OP_1^2} \cdot \overline{OP_2^2} \sin^2 \theta = \overline{OP_1^2} \cdot \overline{OP_2^2} - \overline{OP_1^2} \cdot \overline{OP_2^2} \cdot \cos^2 \theta.$$

But

$$(3) \quad \cos \theta = \frac{x_1 x_2 + y_1 y_2 + z_1 z_2}{\pm OP_1 \cdot OP_2}$$

and

$$(4) \quad \overline{OP_1^2} = x_1^2 + y_1^2 + z_1^2; \quad \overline{OP_2^2} = x_2^2 + y_2^2 + z_2^2.$$

Substituting (3) and (4) in (2), we have

$$(5) \quad 4A^2 = (x_1^2 + y_1^2 + z_1^2)(x_2^2 + y_2^2 + z_2^2) - (x_1 x_2 + y_1 y_2 + z_1 z_2)^2.$$

Again, in the  $xy$ -plane by plane analytic geometry we have

$$A_x = \frac{1}{2} \begin{vmatrix} x_1 & y_1 \\ x_2 & y_2 \end{vmatrix}$$

from which

$$(6) \quad 4A_z^2 = \begin{vmatrix} x_1 & y_1 \\ x_2 & y_2 \end{vmatrix}^2.$$

Similarly,

$$(7) \quad 4A_x^2 = \begin{vmatrix} y_1 & z_1 \\ y_2 & z_2 \end{vmatrix}^2 \quad \text{and} \quad 4A_y^2 = \begin{vmatrix} z_1 & x_1 \\ z_2 & x_2 \end{vmatrix}^2.$$

Equations (5), (6) and (7) when substituted in (1) establish the theorem.

11. *Direction cosines of the principal normal to a curve at a point.* In the application of the calculus to the theory of space curves an important problem is the determination of the direction cosines of the principal normal to the curve at a point. This is usually done by finding expressions for the direction cosines of the tangent and binormal, and combining these with the equations resulting from the fact that each element of a certain third order determinant is equal to its cofactor.

The following method seems simpler and more direct. From the expression which gives the curvature of the curve we have

$$(1) \quad \frac{1}{\rho^2} = x''^2 + y''^2 + z''^2,$$

where  $\rho$  is the radius of curvature of the curve at the point, and  $x''$ ,  $y''$ ,  $z''$  denote, respectively, the second derivatives of  $x$ ,  $y$ ,  $z$  as to the arc length  $s$  along the curve.

If in (1) we multiply both sides by  $\rho^2$ , we can write

$$(2) \quad (\rho x'')^2 + (\rho y'')^2 + (\rho z'')^2 = 1.$$

Now equation (2) tells us that  $\rho x''$ ,  $\rho y''$ ,  $\rho z''$  are the direction cosines of some line in space. At this point in the development we have available the formula  $\Sigma x'x'' = 0$ , where  $\Sigma$  indicates the summation of terms of the type written after cyclic interchange on the letters  $x$ ,  $y$ ,  $z$ . Consequently  $\Sigma \rho x'x'' = 0$ , which says that the line in question is perpendicular to the tangent at the point  $P(x, y, z)$ .

Imagine now a line on  $P$  and in the direction specified by the direction cosines in question. The coördinates of a point  $Q$  on this line and a unit's distance from  $P$  are  $(x + \rho x'', y + \rho y'', z + \rho z'')$ . This point  $Q$  lies in the osculating plane at  $P$  since its coördinates just noted are readily seen to satisfy the equation

$$\begin{aligned}
 &X - x, \quad x', \quad x'' \\
 (3) \quad &Y - y, \quad y', \quad y'' = 0 \\
 &Z - z, \quad z', \quad z''
 \end{aligned}$$

of this osculating plane at  $P$ . Our line with the direction cosines in question is thus seen to be perpendicular to the binormal. Since our line  $PQ$  with direction cosines  $\rho x'', \rho y'', \rho z''$  is on  $P$  and has already been shown perpendicular to the tangent, it must be the principal normal. We are thus led to the usual equations for the direction cosines of the principal normal

$$l = \rho x'', \quad m = \rho y'', \quad n = \rho z''.$$

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# A STUDY OF THE ACTION OF SODIUM SULFIDE ON POLY-METHYLENE HALIDES AND THE FORMATION OF "POLYTHIOPHANES"<sup>1</sup>

By R. W. BOST<sup>2</sup> and M. W. CONN<sup>3</sup>

During the past few years considerable amounts of certain thiophanes were used in studies being carried out in this laboratory. In the synthesis of these thiophanes, it was observed that under certain conditions, appreciable amounts of polymers were obtained. In fact, the authors have observed three distinct products in thiophane synthesis: the unimolecular sulfide, a polymerized product containing sulfur and a product containing both halogen and sulfur. Only small amounts of the latter product have been obtained and for this reason it has not been studied.

Braun and Trumpler<sup>4</sup> isolated a polymer in the synthesis of trimethylene sulfide. They report a melting point of 65° but apparently did not study it further. Other investigators<sup>5, 6, 7, 8</sup> have observed polymers of trimethylene sulfide but no further studies on them have been reported.

Since the polymers herewith reported were obtained during the preparation of thiophanes, the authors have named them "polythiophanes." In this paper will be given a study of their mode of formation, isolation, purification, and certain physical and chemical properties.

From the results given in Table I will be noted the effect of such

<sup>1</sup> This paper contains results obtained in an investigation of "The Preparation and Properties of Thiophanes" listed as Project 41 of the American Petroleum Institute Research. Financial Assistance in this work was received from a research fund of the American Petroleum Institute donated by Mr. John D. Rockefeller. This fund was administered by the Institute with the cooperation of the Central Petroleum Committee of the National Research Council.

<sup>2</sup> Director of Project 41.

<sup>3</sup> American Petroleum Institute Research Fellow.

<sup>4</sup> Braun and Trumpler, Ber. **43**: 545. 1910.

<sup>5</sup> Mansfield, Ber. **19**: 696. 1886.

<sup>6</sup> Hagelberg, Ber. **23**: 1083. 1890.

<sup>7</sup> Autenreith and Wolff, Ber. **32**: 1368. 1899.

<sup>8</sup> Grischkevitch-Trochimoviski, J. Russ. Phys. Chem. Soc. **48**: 880. 1916.

factors as period of addition of halide, ratio of sodium sulfide to halide used, and time of heating on polymer formation. In run (b) are given the results when the sodium sulfide is added to the halide. Due to the high cost of the tetramethylene and pentamethylene halides, very few variations of conditions with these were made, hence the results with the trimethylene halides are of greater value in studying the effects of various conditions on polymer formation.

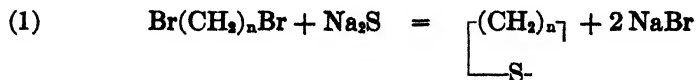
TABLE I  
TABULATION OF DATA ON THE PREPARATION OF THIOPHANES AND POLYMER FORMATION

HALIDE USED	MOLES OF HALIDE USED	PERIOD OF ADDITION OF HALIDE	AMOUNT OF SODIUM SULFIDE USED	YIELD OF THIO- PHANE	YIELD OF POLYMER	TIME OF HEATING
Preparation of trimethylene sulfide						
(a) C <sub>3</sub> H <sub>6</sub> Br <sub>2</sub>	1	1.5 hrs.	Calcd.	16.5%	None	8 hrs.
(b) C <sub>3</sub> H <sub>6</sub> Br <sub>2</sub>	1	2 hrs.*	Calcd.	10.6%	11%	8 hrs.
(c) C <sub>3</sub> H <sub>6</sub> Cl <sub>2</sub>	1.5	Dropwise	20% excess	7.5%	36%	8 hrs.
(d) C <sub>3</sub> H <sub>6</sub> Cl <sub>2</sub>	1	1.5 hrs.	Calcd.	18.5%	None	0.5 hrs.
(e) C <sub>3</sub> H <sub>6</sub> Cl <sub>2</sub>	1	1.5 hrs.	Calcd.	23.2%	None	8 hrs.
Preparation of tetramethylene sulfide						
(f) C <sub>4</sub> H <sub>8</sub> Br <sub>2</sub>	0.25	Dropwise	Calcd.	42%	None	5 hrs.
(g) C <sub>4</sub> H <sub>8</sub> Br <sub>2</sub>	0.33	10 min.	Calcd.	10%	2.5%	1 hr.
Preparation of pentamethylene sulfide						
(h) C <sub>5</sub> H <sub>10</sub> Cl <sub>2</sub>	0.67	1.5 hrs.	Calcd.	43%	None	8 hrs.
(i) C <sub>5</sub> H <sub>10</sub> Cl <sub>2</sub>	0.90	20 min.	50% excess	16%	12%	8 hrs.

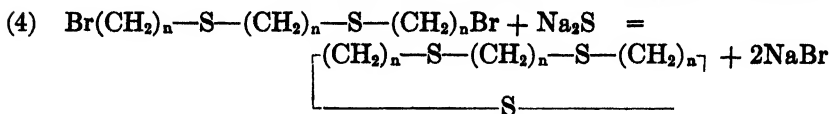
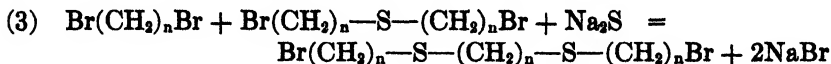
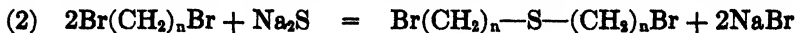
\* Sodium sulfide was added to the halide.

The questions which next arise are: What is the mechanism of the reaction between sodium sulfide and the dihalide to give polymers? To what extent does the reaction go? What is the nature of the sulfur linkage?

If the reaction between the reactive groups of each molecule is simultaneous when they come into contact, then we should obtain no polymer but should get the unimolecular sulfide in accordance with the following equation:



Obviously, since polymers are formed in certain cases, some side reactions must take place. The most logical reactions, as indicated by the products obtained, can be expressed by the following equations:

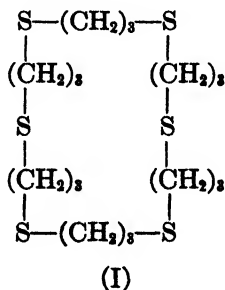


In the purification of the unimolecular sulfide obtained in equation (1) small amounts of a product containing a halogen and sulfur were obtained. Equations (2) and (3) serve to explain its mode of formation. Likewise, equation (4) explains "polythiophane" formation.

It is evident therefore that reactions (2) and (3) may go on indefinitely, and that the number of atoms of sulfur in the "polythiophane" will depend upon the extent to which reactions (2) and (3) have gone. The factors which determine the extent to which reactions (2) and (3) may go will not be discussed in this paper.

If equation (4) expresses the mode of formation of "polythiophanes,"

then they should contain the  $\text{—}\overset{\textstyle |}{\text{C}}\text{—S—}\overset{\textstyle |}{\text{C}}\text{—}$  linkage. For example, the molecular weight of trimethylene "polythiophane" shows it to have the empirical formula of  $(\text{C}_3\text{H}_6\text{S})_x$ . It is possible to express this formula by the following structural formula:



Structurally then, we have in formula (I) six sulfide linkages. Some of the possible reduction products of formula (I) are hydrogen sulfide, propyl mercaptan, trimethylene thioglycol, and propane. The fact

that hydrogen sulfide and propane were obtained on vigorous reduction of this "polythiophane" indicates formula (I) or a  $\begin{array}{c} | & & | \\ -C & -S- & C- \\ | & & | \end{array}$  linkage as being the true linkage. The formation of sulfoxides and the mechanism of the reaction of sodium sulfide on dihalides as shown above also supports this structure.

#### EXPERIMENTAL

*Preparation of thiophanes.* To a solution of anhydrous sodium sulfide in absolute alcohol contained in a 3-neck balloon flask fitted with a stirrer and mercury seal, a condenser and a dropping funnel, was added the dihalide. After all the halide had been added, the stirring was continued and the mixture heated gently on a steam bath. When the reaction had gone to completion, the product was allowed to cool.

*Isolation of "polythiophanes."* The cool product was poured into a separatory funnel and diluted with two volumes of ice water and shaken. At this point the "polythiophane" separated as a solid or semi-solid, the thiophane floats on the top as an oil while the sodium halide goes into solution. The thiophane is removed by extraction with petroleum ether while the "polythiophane" is removed by decantation and dried. It is then dissolved in hot benzene, boiled with charcoal, filtered and the benzene allowed to evaporate.

*Purification of polythiophanes.* The method of purification was essentially that of Braun and Trumpler.<sup>9</sup> The "polythiophane" is soluble in all proportions in chloroform and is reprecipitated by the addition of ethyl ether. Such precipitations of polymers from chloroform were carried out 15 to 20 times without appreciable loss of material. Usually about 20 such precipitations were sufficient to get a product having a constant melting point. The precipitation of the "polythiophane" of trimethylene sulfide required that the chloroform solution be surrounded by a freezing mixture ( $-10^{\circ}$  to  $-15^{\circ}\text{C}.$ ) to prevent the separation of the precipitate as an oil.

Solubility determinations showed these compounds to be soluble in all proportions in carbon tetrachloride and chloroform. They are soluble in benzene at elevated temperatures. Brombenzene dissolves trimethylene "polythiophane" in all proportions. The "polythiophanes" are only partially soluble in carbon disulfide. Methyl and ethyl alcohols,

<sup>9</sup> Braun and Trumpler, Ber. 43: 549. 1910.



acetone, ether, acetic acid, and ethyl acetate have no appreciable action on these compounds.

*Molecular weight determinations.* Due to the insolubility or partial solubility of "polythiophanes" in most common solvents, the Rast Method<sup>10</sup> was adopted for the determination of molecular weights. Other methods for the determination of molecular weights were attempted but were unsuccessful. The results of the molecular weight determinations are given in Table II.

*Reduction of trimethylene "polythiophane."* The reduction was carried out in an apparatus consisting of a 3-neck balloon flask containing a mercury seal and stirrer, a dropping funnel and an outlet tube connected

TABLE II  
DATA ON MOLECULAR WEIGHT OF "POLYTHIOPHANES"

SUBSTANCE	MOLECULAR WEIGHT	MULTIPLE OF THIOPHANE
$(C_6H_8S)_x$	440.6	6
$(C_6H_{10}S)_x$	525	5
$(C_6H_{12}S)_x$	458.7	4

TABLE III  
SULFUR ANALYSES OF "POLYTHIOPHANES"

COMPOUND	PER CENT SULFUR CALCULATED	PER CENT SULFUR FOUND
$(C_6H_8S)_6$	43.26	42.54-42.38
$(C_6H_{10}S)_6$	31.39	30.91-30.97
$(C_6H_{12}S)_4$	27.60	26.43-26.63

with a glass coil around which cold water circulated. This in turn was connected with two towers containing bismuth trichloride and hydrochloric acid, these were connected with U tubes containing soda lime and calcium chloride respectively, the latter of which was connected with a glass coil surrounded by solid carbon dioxide which in turn was connected with a safety trap and bubble counter. The reaction flask was supported on a water bath maintained at 80°C.

In the 3-neck balloon flask was placed 100-150 grams of zinc dust and 100 ml. of water. When all connections were tight, the system was swept out with pure hydrogen from a cylinder. The "polythiophane" was quickly introduced into the reaction flask. Concentrated hydro-

<sup>10</sup> Rast, Ber. 55: 1051. 1923.

chloric acid was added dropwise while the mixture was vigorously stirred. The first coil was surrounded with ice water to condense all high-boiling substances. The condensate in this coil was tested for thioalcohols but all tests were negative. Hydrogen sulfide was positively identified in the bismuth trichloride towers. The soda lime and calcium chloride tubes were designed to remove water vapor. Coil number 2 surrounded with solid carbon dioxide was used to collect any propane which might be formed. At the end of the reduction the ends of the glass coil were sealed while the latter was still surrounded with solid carbon dioxide. Appreciable amounts of propane were identified in the reaction. In this connection, it is very interesting to note that the vigorous reduction of the

$$\begin{array}{c} | \quad | \\ -C-S-C- \\ | \quad | \end{array}$$

linkage gives  $H_2S$  and a hydrocarbon but no appreciable amount of mercaptan.

TABLE IV

CHARACTERISTICS OF "POLYTHIOPHANES" AND THE OXIDATION PRODUCT OF PENTAMETHYLENE "POLYTHIOPHANE"

	$(C_5H_8S)_x$	$(C_5H_{10}S)_x$	$(C_5H_{12}SO)_x$	$C_5H_{12}S_2$
Color.....	Cream	Light cream	Snow white	Grayish white
Crystalline form....	Amorphous powder	Amorphous powder	Amorphous powder	Amorphous powder
M.P., °C.....	51-2	66-7	220 (decomp.)	67-9

*Oxidation of "polythiophanes."* These oxidations were carried out under reflux, using aqueous permanganate and a carbon tetrachloride solution of the "polythiophane." The refluxing and addition of potassium permanganate were continued until the color of permanganate remained. The reaction mixture was cooled, and treated with aqueous sulfur dioxide to remove the excess permanganate. When the water and carbon tetrachloride were removed, an amorphous white precipitate remained. The crude product was boiled with chloroform to remove any of the original "polythiophane" and finally boiled with several portions of water to remove adsorbed inorganic salts. The oxidation products of the "polythiophanes" were insoluble in carbon tetrachloride, chloroform, ethyl and methyl alcohols, ether, acetone, benzene, toluene, brombenzene, glacial acetic acid, n-haptane, and carbon disulfide. Only the oxidation product of pentamethylene "polythiophane" could be

obtained in sufficiently pure form for analysis. Upon analysis the product was shown to be a sulfoxide.

<i>Analysis</i>		
(C <sub>6</sub> H <sub>10</sub> SO) <sub>6</sub> .	Sulfur per cent Calculated.....	27.14
	Sulfur per cent Found.....	26.94
		27.24

#### CONCLUSIONS

1. Certain factors affecting "polythiophane" formation have been studied.

2. The isolation, purification, physical and chemical properties of several "polythiophanes" are described.

3. A mechanism of their mode of formation, as well as their structure, is offered.

4. Vigorous reduction of "polythiophanes" containing the  $\begin{array}{c} | \\ -C-S- \\ | \end{array}$  linkage gives hydrogen sulfide and a hydrocarbon but no mercaptan.

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# NEW NORTH AMERICAN SPECIES OF MAYFLIES (EPHEMERIDA)

By JAY R. TRAVER

## PLATE 16

In the following article are presented descriptions of several new species of mayflies in three subfamilies of the family Baetidae.

### SUBFAMILY LEPTOPHLEBIINAE

Examination of specimens, both nymphs and imagoes, of *Leptophlebia marginata* Linn., shows that this species is quite distinct from those North American species which have previously been described in the genus *Leptophlebia*. All of these species, with the exception of *johnsoni* McD., which with *gracilis* Traver (in *Blasturus*) stands nearer to *Leptophlebia* than to *Paraleptophlebia*, I am transferring to the genus *Paraleptophlebia*.

#### *Paraleptophlebia sculleni*, sp. nov.

##### Male imago

*Size.* Body  $6\frac{1}{2}$  mm.; tails  $7\frac{1}{2}$  mm.; wing  $6\frac{1}{2}$  mm.

*Head.* Reddish brown. Antennae pale brown.

*Thorax.* Reddish brown, the pleural sutures paler.

*Legs.* Pale. Fore leg missing, except basal portion, which is faintly yellowish. Middle and hind legs white.

*Wings.* Semi-hyaline, white. All veins white; cross veins almost invisible. Stigmatic cross veins few, simple, and slightly curved.

*Abdomen.* Segment 1, tergites 8 and 9, and all but the basal margin of tergite 7, bright reddish brown; opaque. Segments 2-6 hyaline; segment 2 strongly tinged with reddish brown, 3-6 whitish with smoky markings. Posterior margins of tergites smoky brown, this color extending forward on tergite 6 so that only the basal portion is pure white. Tergites 2-5 faintly shaded with smoky tinge along the mid-dorsal region. Tergite 10 yellowish brown with reddish tinge, the mid-dorsal line and posterior margin darker. A rather wide smoky brown line marks the entire length of the pleural fold. Sternites 8 and 9,

and apical half of sternite 7, pale reddish to yellowish brown. Ganglionic areas reddish brown.

*Genitalia.* Yellowish brown. Long segment of forceps widens suddenly at the base; toward the tip it tapers very slightly. Penes separated by a U-shaped notch, which is almost closed at the top by the approximated inner margins of the penes. A rounded lobe forms the inner apical margin of each division of the penes, laterad of which the apical margin slopes backward obliquely, to end in a minute curved hook. Reflexed spur present; long, wide at the base and tapering suddenly at the tip, which is slightly recurved.

*Tails.* White; joinings also white, slightly opaque.

Holotype—Male imago. Collected by Prof. H. A. Scullen at Corvallis, Oregon, on May 31, 1931. No. 1264.1 in Cornell University collection.

Named for Prof. Scullen, who collected the single specimen representing the species in our collection.

*Paraleptophlebia falcula*, sp. nov.

Head, thorax, and end segments of abdomen dark reddish brown; middle abdominal segments pale with smoky markings.

Male imago

*Size.* Body 7 mm.; tails 9 mm.; wing 7 mm.

*Head.* Reddish brown. Clypeus pale. Antennae pale brown.

*Thorax.* Dark reddish brown. Spaces between pleural sclerites light brown, especially around middle leg and anterior to wing roots. Distal half of mesosternum slightly paler than remainder of thoracic sternum.

*Legs.* Pale. Femora faintly washed with yellow, and with a brownish mark at the apex. On the fore leg, this knee mark is dark reddish brown, and extends over the base of the tibia.

*Wings.* Hyaline, white. Slight reddish tinge at extreme base of subcosta and radius of fore wing. All veins pale, almost invisible. Costal cross veins in the pterostigmatic area simple, somewhat slanted, evenly spaced, and 10–11 in number.

*Abdomen.* Segments 1 and 8–10 opaque, wholly reddish brown, darker above. Tergite 7 reddish brown except for a pale basal margin; 7th sternite pale and semihyaline, except for central portion, which is occupied by a large triangular yellowish ganglionic mark. At about the

middle of this yellow blotch, and again at its anterior end, are small reddish brown spots. Posterior margins of tergites 7-9 very dark reddish brown. On tergite 7, a dark triangle from the posterior dark band on each side extends forward for more than one-half the length of the tergite, leaving the margin next to the pleural fold and the antero-lateral angle pale. Segments 2-6 semi-hyaline, pale, with faint smoky tinge. Posterior margins pale, opaque. On each tergite a smoky transverse band, widest and darkest at the postero-lateral angles, occurs immediately anterior to the pale posterior border. On tergite 2, a dark reddish brown spot is present on each side within this smoky band, above the postero-lateral angle. A single short black dash marks each stigma. Sternite 2 washed with pale reddish brown. Ganglionic areas yellowish brown.

*Genitalia.* Forceps and forceps base pale yellowish, penes yellowish brown. Apex of each triangular division of the forceps base prolonged into a long slender process. Long joint of forceps widest at the middle of its length. Penes separated by an open U-shaped cleft deeper than wide. Tips of penes sharply triangular. Reflexed spurs long, sickle-shaped, acute at the tip; at first bending inward until they almost touch, then directed outward.

*Tails.* White, unmarked.

Holotype—Male imago. Collected by Prof. H. A. Scullen at Corvallis, Oregon, July 4, 1907. No. 1265.1 in Cornell University collection.

*Paraleptophlebia georgiana*, sp. nov.

A dark reddish brown species, in general appearance very similar to *ontario* McD.

Male imago

*Size.* Body 5 mm.; tails 6 mm.; wing 5 mm.

*Head.* Reddish brown. Antennal filament pale brown at base, white distally.

*Thorax.* Dark reddish brown, somewhat paler on pleura and sternum. Lateral margins of pronotum, and scutellum of mesothorax, blackish brown.

*Legs.* White, femora faintly tinged with yellow. Apical ends of femora and basal ends of tibiae pale yellowish brown.

*Wings.* Hyaline, white. Costal, subcostal, and radial veins reddish

brown at extreme base; pale yellowish for remainder of their length. Humeral cross vein reddish brown. All other veins pale; cross veins almost invisible. Costal cross veins of the pterostigmatic area simple, very slightly curved, 8-9 in number.

*Abdomen.* Dark reddish brown dorsally, paler ventrally. Posterior margins of all segments darker reddish brown, these bands continuous around the segments, paler on the sternites. Sternites 1 and 7-10 washed with reddish brown; intermediate sternites pale yellowish. Pleural fold margined with a narrow dark line. A single short black dash marks each stigma.

*Genitalia.* Forceps base reddish brown; forceps and penes paler brown. Long joint of forceps widest at base, narrowed for a short distance, and then widened again about one-third from the base; beyond this point narrowed slightly for the remainder of its length. Penes separated by a V-shaped cleft, longer than wide, and narrowed at the apex. Apex of each division of the penes rounded, and sloping backward obliquely to a blunt projection on each side. Rounded processes at tip approach one another slightly. Reflexed lobe blunt at tip, about equally wide in all parts.

*Tails.* Whitish. Joinings at base narrowly darker.

#### Male subimago

Wings pale smoky brown. Legs and tails yellowish. Venter of abdomen entirely pale reddish brown. Otherwise similar to imago.

#### Female imago

Apart from usual differences, similar to male except as indicated. Posterior half of anterior sclerite of the mesosternum yellow. Legs pale yellowish. Wings faintly tinged with light amber. Longitudinal veins of the costal border in the fore wing pale brown, those in the middle area pale yellowish. Costal cross veins in the pterostigmatic area somewhat more distinct. Tails faintly tinged with amber. A dark red spot on the middle of the posterior margin of the 7th sternite.

#### Female subimago

Wings, legs, and tails as in male subimago. Otherwise similar to female imago.

**Holotype—Male imago.** Collected by Prof. P. W. Fattig at Swamp Creek near Dalton, Ga., in June 1931. No. 1266.1 in Cornell University collection.

Allotype—Female imago. Same collector, same data. No. 1266.2 in the Cornell University collection.

Paratypes—1 female imago; 1 male and 1 female subimago. Same collector, same data. No. 1266.3-5 in the Cornell collection.

In addition to the types, 3 other female subimagoes were taken by Prof. Fattig at the same time and place.

This species may be distinguished from *ontario* McD. by (1) the slightly smaller size; (2) the paler antennae and legs; (3) the relatively paler venter of the abdomen; and (4) details in the structure of the genitalia. The reflexed lobe of the penes tends to be directed laterally in *ontario* McD., and is slightly widest near the middle of its length. In *georgiana*, this spur is longer, directed backward rather than laterally, and is not wider at the middle than elsewhere. The apical notch between the lobes of the penes is relatively deeper also, in *georgiana*. The ganglionic areas of *ontario* are usually dark brown, a condition not found in *georgiana*.

*Paraleptophlebia compar*, sp. nov.

A species very similar in general appearance to *californica*, sp. nov., but in type of genitalia resembling *associata* McD. Distinguished from the latter species by its much paler color, and by the longer reflexed spurs on the penes.

Male imago

*Size.* Body  $7\frac{1}{2}$  mm.; tails 9 mm.; wing  $7\frac{1}{2}$  mm.

*Head.* Reddish yellow. Clypeus and median carina yellow. Bases of antennae encircled by a blackish line. Antennae pale. Bases of ocelli ringed with purplish black.

*Thorax.* Reddish brown. Anterior margin of pronotum, its mid-dorsal line, and pencillings along the lateral and antero-lateral margins, blackish. Interspaces between pleural sutures pale. A white or yellowish spot just cephalad of the mesothoracic scutellum. Meso- and metanota, and sternal sclerites, tinged with yellow. Purplish black pencillings in an irregular line from the base of the fore wing to fore coxa; from base of hind wing to middle leg; a distinct black line above hind coxa, and black marks around its base.

*Legs.* Pale; white tinged faintly with yellowish. Apical end of femur and basal end of tibia of fore leg reddish brown; on middle and hind legs, pale yellowish brown.



*Wings.* Hyaline, white. Longitudinal veins in anterior half of fore wing pale brown. All other veins colorless; cross veins almost invisible. Costal cross veins in the pterostigmatic area simple, somewhat slanting, evenly spaced and 8-10 in number.

*Abdomen.* Pale, with smoky markings and bands on the tergites. Segments 1-5 and all of 6 except the posterior central portion of the tergite, whitish and semi-hyaline. Posterior half of tergite 6, and segments 7-10, opaque, yellowish. A rather broad purplish grey band on the posterior margin of each tergite, and on each sternite on its posterolateral angle only. Pleural fold marked by a purplish grey band within which is a narrow black pencilling. Lateral margins of tergites with faint smoky to purplish grey clouds. A small blotch in each posterolateral corner. A more diffuse blotch slightly anterior to center on each side, a little above the pleural fold. Indications on some specimens of a narrow dark geminate mid-dorsal line on the basal half of tergites 2-3, and 7-9. Dorsal area of tergites unclouded. Ganglionic area opaque white. Sternite 1 tinged with yellow.

*Genitalia.* Forceps base pale reddish brown; forceps brown at base, shaded with purple in the middle, and pale distally. Penes quite similar to *associata* McD., but with longer reflexed lobes. Long joint of forceps gradually enlarged at base. Tips of penes smoky brown. Penes separated by a rounded notch almost as wide as deep, which is partially closed at the top by the approximated inwardly-directed processes on the inner margin of each division of the penes.

*Tails.* Pale purplish grey at base, becoming paler gradually; tips silvery white. Joinings dark purplish grey except at tip, where they are not darker than the segments.

#### Male subimago

Wings pale smoky brown. Notum of mesothorax with prominent pale blotches and markings. Scutellum and the area immediately anterior to it, wholly pale yellowish white. Mid-dorsal line pale, with two widened areas,—one just posterior to the praescutum, the other at the posterior margin of the scutum. Scutum outlined with dark brown; a pale line margins the dark one on the inner side. A pale line anterior to the wing roots. First fore tarsal joint shaded with brown basally; all tarsal joinings narrowly dark.

#### Female imago

Similar to male except as indicated. Thorax paler, not darker in color than abdomen. All longitudinal veins of both wings dark brown,

strongly defined. Costal cross veins of pterostigmatic area pale brown. Abdomen uniformly orange-tinged (before deposition of eggs).

#### Female subimago

Wings tinged with orange in addition to the smoky brown tone. Even more white on the mesonotum than is present on the male subimago, a pale line extending completely around its margin. All joints of fore tarsus brownish at base. Otherwise as in male subimago.

**Holotype**—Male imago. Collected by Dr. David Shepherd on Waddell Creek, Rancho del Oso, Calif. No. 1281.1 in the Cornell University collection.

**Allotype**—Female imago. Same data. No. 1281.2 in the Cornell collection.

**Paratypes**—2 male imagoes, 1 male subimago, 7 female subimagoes. Same data. No. 1281.3–9 in the Cornell University collection. (1 male imago and 2 female subimagoes in the Stanford University collection.)

#### *Paraleptophlebia californica*, sp. nov.

##### Male imago

**Size.** Body 8 mm.; tails 8 mm.; wing 8 mm.

**Head.** Reddish brown. Margin of clypeus purplish black. Antennae pale brown. Vertex dark red, deeper at the bases of the ocelli.

**Thorax.** Thoracic notum deep reddish brown. Pronotum whitish at the center of the posterior margin; mid-dorsal line, and pencillings on each side and in the postero-lateral angles, black. An indistinct paler spot anterior to the mesonotal scutellum. Pleura reddish with yellow shading, the sutures reddish black. Metanotum brighter reddish laterally. Blackish pencillings on the pleura of the mesonotum from the base of the fore wing to the fore coxa, and on the coxae and antecoxal pieces of the middle and hind legs. Sternum red, the sutures reddish brown.

**Legs.** Fore legs reddish, the tarsi paler. Middle and hind legs yellowish, the tarsi tinged with reddish.

**Wings.** Hyaline. Main longitudinal veins light reddish brown; a reddish brown spot at the extreme base of each wing. Stigmatic area opaque whitish; the cross veins curved, simple, a few forking near the costal margin.

**Abdomen.** Segment 1 largely opaque. Segments 2–7 semi-hyaline,

pale reddish brown much obscured by smoky brown markings. Posterior margins of all segments darker reddish brown, this dark band continuous around the entire segment. On each side of tergites 2-9, a smoky oblique band extends inward from near the antero-lateral angle almost to the median line, where it is joined by the smoky submedian oblique streaks on each side of the pale reddish median area. Another less oblique streak, extending inward and forward from the postero-lateral angle, joins the anterior streak near its origin. Each tergite thus appears to be crossed near the center by a smoky zigzag band. Pleural fold margined by a dark line; dark stigmatic marks present. Tergites 6 and 7, the apical portion of tergite 5, and all of tergites 8-10, tinged with deeper reddish brown. Sternites only slightly paler than the tergites, except for a paler area near the lateral margin.

*Genitalia.* Golden brown; tips of penes sometimes tinged with purplish brown. Forceps widened gradually toward the base. Penes separated apically by a deep rounded notch, into which projects from the inner margin of each division of the penes a short blunt process. Almost opposite this process, on the outer margin, a rather similar projection is directed outward. Apex of penes rounded, sloping obliquely on each side to the above-mentioned blunt projections. Reflexed spur widest at the base, tapering gradually to a sharp point at the tip.

*Tails.* Pale smoky brown, darker at the base. In the basal third the basal portion of each segment is darker than the distal margin. Joinings not darker.

#### Female imago

Head yellowish, with black shading around the bases of the ocelli; a black streak extends down on each side of the median carina from the base of the antennae. Thorax paler red than in the male, the black markings more prominent. Fore leg pale reddish; a reddish brown band at the apex of the femur; the first three tarsal joints smoky except at the tips. Middle and hind legs as in the male. Venation rather deeper reddish brown than in the male; the stigmatic costal cross veins are also reddish brown.

#### Female subimago

Two female subimagoes, with smoky amber-tinged wings and markings very similar to those given above, are tentatively placed in this species.

## Nymph?

Two mature nymphs, in the same vial with one of the female subimagoes, may belong to this species; the color pattern of the abdomen would seem to bear out this possibility. These nymphs have mandibles which are quite similar in their general appearance and line of development to those of the eastern species *swannanoa* Traver. Gills, however, are more like those of the western *packii* Ndhm., being wider than are the gills of any known eastern species (lanceolate rather than narrowly lanceolate).

Holotype—Male imago. Collected by Dr. David Shepherd on Waddell Creek, Rancho del Oso, Calif. No. 1280.1 in the Cornell University collection.

Allotype—Female imago. Same data. No. 1280.2 in the Cornell collection.

Paratypes—3 male imagoes, 1 female imago, 1 male subimago, 1 female subimago. No. 1280.3–6 in the Cornell collection. (1 male and 1 female imago in the Stanford collection.

In general appearance, this species is very close to *compar* n. sp., but is rather darker in color, especially on the venter of the abdomen. The venation is also darker in most specimens. The genitalia of the two species are quite different, however. The deep rounded apical notch and the shape of the reflexed spur in *californica* should render it readily distinguishable from *compar*, in the male sex.

*Blasturus vibex*, sp. nov.

## Male imago

*Size.* Body 13 mm.; tails 27 mm.; wing  $10\frac{1}{2}$ – $12\frac{1}{2}$  mm.

*Head.* Frons yellowish brown. A blackish area along base of median carina, on each side. A dark transverse streak below each eye. Antennae brown. Vertex blackish.

*Thorax.* Very dark reddish brown. Posterior margin of pronotum pale yellowish along middle area. A pale yellow line anterior to wing roots, bordering the dark notum. Sutures of pleura pale yellowish brown.

*Legs.* Fore leg dark brown, femur and tibia somewhat reddish. Middle and hind legs yellowish to pale reddish brown.

*Wings.* Hyaline. A dark brown streak extends obliquely across the fore wing, overspreading the entire pterostigmatic area and zigzag-

ging inward and downward across the end of the bisector of the median fork. It extends almost to the outer margin of the wing a short distance from the anal angle, and ends just beyond the bisector of the cubital fork. Longitudinal veins of the fore wing reddish brown, cross veins paler brown. Costal cross veins before the bulla barely visible, 9-10 in number. Cross veins in the stigmatic area numerous, crowded, irregular, and tending to fork or anastomose, or both. No brown stain on hind wing. Veins pale yellowish, except the main veins along the costal margin, which are pale brown.

*Abdomen.* Dark reddish brown, the basal and apical segments darker than the middle ones. Posterior margins of middle segments pale, as is also the margin of the pleural fold, in this area. Sternites not paler than tergites. Pale mid-dorsal line and submedian pale oblique streaks visible, but somewhat obscured by the dark background.

*Genitalia.* Yellowish brown. Apical spine of the penes long and sharp-pointed. Reflexed spur not long enough to reach to the base of the cleft between the penes. A shallow indentation only, on the upper portion of the outer margin of each division of the penes.

*Tails.* Dark reddish brown, narrowly and regularly black at the joinings. Middle tail  $\frac{1}{3}$  as long as the lateral tails.

#### ? Female imago

A female imago, tentatively associated with the above-described male, lacks the apical zigzag brown band on the fore wing. Only the pterostigmatic area is brown-stained. Subanal plate ends in two broadly rounded lobes, separated by a broadly rounded notch.

*Holotype*—Male imago. Collected by Prof. H. A. Scullen at Corvallis, Oregon, April 16, 1931. No. 1263.1 in Cornell University collection.

*Paratype*—Male imago. Same collector. May 16, 1930. No. 1263.3 in the Cornell collection.

The female imago, taken at Corvallis on March 28, 1930, by Mr. Loring Hudson, is not included among the type material.

This species is mentioned by Dr. McDunnough in his recent description of *Blasturus pacificus* (Canad. Ent. 65: 156, 1933) as a probable variant of the latter. The two males we have show great similarity in structure of genitalia to Dr. McDunnough's new species, but it is also true that in this genus the differences in genitalic structure between closely allied species are not great. I venture, therefore, to describe

*vibex* as a new species, although it may later fall as a synonym of *pacificus*.

*Habrophlebiodes annulata*, sp. nov.

Male imago

*Size.* Body  $4\frac{1}{2}$  mm.; wing  $4\frac{1}{2}$  mm.

*Head and thorax* dark reddish brown; no pale markings. Eyes large, contiguous dorsally. Notum darker than pleura and sternum.

*Legs.* Reddish brown. Femora darker than other joints; fore femur much the darkest. All tarsi slightly paler than tibiae. Middle and hind femora with darker apical band, and indication of dark basal streak. Tibiae darker basally.

*Wings.* Longitudinal veins of both wings reddish brown. Humeral vein and cross veins in pterostigmatic area of fore wing pale brown; the latter slightly heavier near the costal margin, and 5-6 in number. All other cross veins entirely pale, almost obsolescent. Both wings have a small dark reddish brown area at the extreme base.

*Abdomen.* Dark reddish brown dorsally; paler reddish brown and sub-hyaline ventrally. Posterior margins of all segments, both tergites and sternites, rather widely banded with darker color, giving the insect an annulated appearance. Dark geminate streak bordering the mid-dorsal line, with very faint indications of pale oblique submedian marks in basal half, except on the last three or four tergites. A narrow dark line, usually double, on and closely parallel to the pleural fold. A very faint crescentic mark may lie parallel to the inner of these dark lines. Sternites have a dark brown streak next to pleural fold. Ganglionic marks may appear darker on the apical segments.

*Genitalia.* Dark reddish brown. Apical extensions of the 9th sternite blunt and rounded at tip. Penes much wider than in *americana*, not narrowed in the central portion as in the latter species.

*Tails.* Missing.

*Holotype*—Male imago. Collected by Prof. R. B. Bird in Oklahoma, March 1932. No. 1260.1 in Cornell University collection.

*Paratype*—Male imago. Same data. No. 1260.3 in the Cornell collection.

*Thraulius presidianus*, sp. nov.

Male imago

*Size.* Body 6 mm.; tails 9 mm.; wing  $7\frac{1}{2}$  mm.

*Head.* Dark reddish brown.

*Thorax.* Dark reddish brown. A paler brown streak anterior to the wing roots; paler area around base of middle leg, on prosternum and anterior portion of mesosternum. .

*Legs.* Fore femur dark reddish brown. Fore tibia dark reddish brown at base, paler brown beyond base. Other legs missing from the single specimen.

*Wings.* Fore wing stained with reddish brown at base, on membrane as well as on veins, this color extending faintly along the costal margin almost to the bulla. Bases of all main longitudinal veins, especially subcosta, radius, and media, deep golden brown; this color becoming fainter on the marginal portions of the veins. Intercalaries and cross veins pale. Humeral vein brown. Costal cross veins before the bulla almost invisible; 11-13 in number. Beyond the bulla these are somewhat better defined, about 23 in number; simple and rather regularly spaced. Veins of hind wing pale in center and marginal areas, purplish brown at base. No basal stain on hind wing.

*Abdomen.* Segment 1 opaque, dark reddish brown. Segments 2-7 semi-hyaline, smoky, shaded with pale reddish brown; this shading less apparent on middle segments. Posterior margins of tergites narrowly darker greyish brown, this dark band preceded by a paler parallel band. Joinings of middle sternites pale, opaque. On tergites 1-3, the pleural fold is margined with dark brown. Segments 8-10 opaque, reddish brown.

*Genitalia.* Penes short and stout, truncate apically, the outer apical margin longer than the inner; separated by a V-shaped cleft. The dorsal extensions of the forceps base are extremely slender and elongate, bearing short spines at the tips. These extensions are dorsad of the forceps but ventrad of the penes, arising from a dorsal extension of the forceps base.

*Tails.* Pale whitish. At base, distinctly ringed with dark purplish brown at joinings. Joinings other than those at base, opaque white.

Holotype—Male imago. Collected by Mr. F. L. Thomas at Presidio, Texas, in August 1931. No. 1261.1 in Cornell Univ. collection.

This species, represented by a single male specimen, is smaller than the northern *albertanus* McD., and differs from that species somewhat in coloration. It may be distinguished from *primanus* Etn. by the lack of the brown stain on the hind wing and the paler abdomen. It does not seem to resemble closely any of the neotropical species of the genus.

*Thraulodes speciosus*, sp. nov.

## Male imago

*Size.* Body  $7\frac{1}{2}$  mm.; tails 15 mm.; wing  $8\frac{1}{2}$  mm.

*Head.* Blackish brown. Eyes deep red (basal portion black). Antennal filament pale brown.

*Thorax.* Reddish brown. Pronotum black on anterior and lateral margins and on basal half of median line. Mesonotum rather yellowish red, brighter in color than remainder of thorax. Tip of scutellum dark brown. Black streak on pleura from base of fore wing to fore coxa. Other black markings around antecoxal pieces of middle and hind legs. Prosternum blackish brown. Large dark brown rounded blotches (ganglionic marks?) on praesternum and sternum on the mesothorax.

*Legs.* Fore femur reddish brown, yellowish at base; two longitudinal black streaks present, one near the base, the other in the apical half. A dark band slightly beyond the middle. Tibia yellowish at center, reddish brown near each end; basal end dark red, apex blackish. Fore tarsus yellow or reddish yellow. Claws and apical two-thirds of distal segment reddish black. Middle and hind legs bright yellow, the femora tinged with red, and with a wide reddish apical band. Middle tibia reddish at base. Claws and apical half of distal tarsal segments reddish brown.

*Wings.* Hyaline, iridescent. The three main longitudinal veins of the costal border of the fore wing golden yellow; other longitudinal veins yellowish brown. Cross veins rather darker brown. Humeral cross vein reddish brown, margined by a brown cloud which is wider on the side away from the base. All basal cross veins in costal and subcostal spaces, and in the following spaces in the basal half of the wing disc, narrowly margined with brown. A small purplish brown cloud at the bulla on the subcosta; another directly below it on the radial sector. Sometimes a much smaller dark spot also on the second branch of the radial sector. Median vein somewhat thickened at its fork. 5 to 7 costal cross veins before the bulla, all but the basal of these prominently margined. In the pterostigmatic area are about 15 costals, of which only the two nearest the bulla are margined. These costals are irregularly spaced, and 2 or 3 of them are forked. In the hind wing, a small, purplish cloud occurs at the base of the subcostal and radius. Veins of the costal margin brownish, others pale. Basal costal cross vein black, in the paratype, also that portion of the subcosta basad of the cross vein.

*Abdomen.* Tergite 1 very narrow, brownish. Tergite 2 dark reddish



brown. Tergite 3 semi-hyaline, pale smoky brown, except for a large reddish triangle in the postero-lateral angle and extending along the pleural fold. Segments 4-6 semi-hyaline, yellowish, the tergites with reddish brown markings. Each tergite has a large reddish triangle in the postero-lateral corner, the edge of which margins the pleural fold except at the extreme anterior border. At the end of this triangle on the pleural fold, a small reddish spot may be present. Wavy black lines, 3-5 in number, are present within this reddish triangle, parallel to the pleural fold, on tergites 4 and 5. A pale smoky cloud partially obscures the basal median portion of tergite 6; similar pale clouds faintly visible in tergites 4 and 5. Tergites 7-10 opaque, red with brownish tinge. All tergites blackish on the posterior margins. Sternites 1-3 and 8-9, reddish. Ganglionic areas marked with reddish brown patches (on apical sternites, almost black).

*Genitalia.* Forceps base and forceps pale brown; tips of forceps purplish. Penes reddish brown. Forceps long, slender, bowed outward strongly from near the base. Distal portion bends inward, the tips approaching one another. Apical median extension of forceps base rather dome-shaped. Each division of the penes is somewhat urn-shaped, flaring at base and apex, slender in central portion. Reflexed spurs of the penes long and slender, directed inward; in normal position the tips cross one another.

*Tails.* Yellowish white. Joinings rather widely purplish black. Near the base, each joining seems composed of a double ring. Further out, alternate joinings are distinctly wider. Beyond the middle, all joinings are equally wide.

#### Female imago

Similar to the male, except in the coloring of the abdomen, which is wholly reddish; tergites with black posterior margins; ganglionic areas of sternites dark reddish brown. Subanal plate excavated at the center of the apical margin.

*Holotype*—Male imago. Collected by Mr. J. A. Kusche in Rustler Park, Chiracahua Mts., Arizona, July 3, 1927. No. 3733 in the collection of the California Academy of Science.

*Allotype*—Female imago. Same data. No. 1267.2 in Cornell collection.

*Paratypes*—1 male and 1 female imago; female, same data as above; male, taken at Cave Creek, Chiracahua Mts., Ariz., June 24,

1927. Male, No. 1267.3 in the Cornell University collection; female in collection of California Academy of Science.

As far as I can determine, this is the first record of a species of *Thraulodes* occurring north of Mexico. This species differs from *mexicanus* Etn. in the possession of prominent basal costal cross veins, and in the structure of the male genitalia. It lacks the amber tinge in the fore wing which is characteristic of *lepidus* Etn. In several details of coloration it differs quite markedly from *hilaris* Etn., but is probably nearer to the latter than to any other of the neotropical species. It differs from *irretitus* Nav. in details of the venation of the hind wing; in having [fewer] stigmatic cross veins anastomosed; and lacks the median band on the femur.

*Choroterpes nanita*, sp. nov.

Paler than other North American species of this genus.

*Size.* Body 8 mm.; tails 8 mm.; wing 6 mm.

Male imago

*Head.* Reddish brown. Clypeus narrowly black on the frontal margin. Eyes reddish brown.

*Thorax.* Dark reddish brown on notum, pleura paler red-brown. Pale areas on each side of mesoscutellum above wing base, and around bases of middle and hind legs. Narrow black pencillings on postero-lateral margins of pronotum and above coxae of all legs. Venter pale; lateral margins of mesosternum pale reddish brown.

*Legs.* Pale whitish. Femur marked with a black longitudinal pencilling for almost its entire length, and a narrow black transverse line at the apex, on its outer surface.

*Wings.* Hyaline. The three main longitudinal veins of the costal margin brownish at base, yellowish brown to the bulla, and pale beyond bulla. Humeral cross vein yellowish brown. No color on wing membranes. All other veins pale. Cross veins, even in stigmatic area, almost invisible.

*Abdomen.* Subhyaline, whitish. Marked dorsally with smoky black zigzag bands across the center of each side of each tergite. A black comma-shaped mark over each stigma. A short black transverse mark on the posterior margin on each side, above the postero-lateral angle. Median line, anterior margin, lateral margin, posterior margin except for the black transverse bar, postero- and antero-lateral angles, and

large triangles on each side of the median line on both anterior and posterior margins, wholly pale. Tergites 9 and 10 washed with yellow. Ventrally pale. Ganglionic areas opaque. A chestnut brown streak borders the pleural fold on sternite 9.

*Genitalia.* Forceps whitish, penes pale yellowish brown. Long joint of forceps considerably swollen in its basal third. Penes acute at tip, together appearing rather pyramidal in outline.

*Tails.* White. Joinings in basal two-thirds black, alternate joinings wider. In distal third, joinings opaque, hardly darker than the segments.

#### Male subimago

Paler than the imago, especially on head and thorax. Thoracic notum rich dark brown with a yellow mid-dorsal line, narrowest at the anterior margin of the mesonotum. Lateral margin of mesonotum anterior to wing root outlined with black; directly above this black line is a yellow line, which curves upward to join the pale mid-dorsal line just above the wing roots.

*Holotype*—Male imago. Collected by Mr. H. J. Parks, Jr., at Austin, Texas, in June. No. 1268.1 in the Cornell University collection.

*Paratype*—Male subimago. Same data. No. 1268.3 in the Cornell collection.

#### *Choroterpes oklahoma*, sp. nov.

A dark brown species with paler brown-mottled abdomen.

#### Male imago

*Size.* Body 7 mm.; tails 8 mm.; wing 8 mm.

*Head.* Dark reddish brown.

*Thorax.* Dark reddish brown, darkest on meso- and metanota and mesothoracic sternum, which appear shiny black. A pale streak anterior to the wing root; pale areas around bases of legs; pleural sutures pale brown.

*Legs.* Fore leg smoky. Femur yellowish brown, ringed with dark brown at base and apex, and with a median brown band. On the inner surface at the apex, a brown streak. A longitudinal black streak outlines it on each side on the outer surface. Knee black. Tibia purplish grey, paler at each end; a brown streak at its apex. Tarsus pale. Middle and hind legs paler. Femora with smoky median bands, a

longitudinal brown streak at each end, and outlined with black on outer surface. On inner surface, pale in center, brown at each end. Knee widely dark brown. Tibiae and tarsi pale, joinings narrowly brown. Upper margin of outer surface of tibia black-lined.

*Wings.* Subhyaline. A brownish area at base of fore wing, on both membrane and veins. Longitudinal veins of costal half yellowish brown; all other veins colorless. Cross veins almost invisible. Stigmatic area opaque white.

*Abdomen.* Smoky brown, paler ventrally, the basal and apical segments dark reddish brown. Posterior margin of each tergite, its median line, and an oblique streak laterad from the posterior margin at the middle line, pale yellowish. Darker smoky brown submedian streaks border the pale median line. Pleural fold pale except for a blackish comma-shaped mark over each stigma. Postero-lateral angles outlined with orange. Sternites 4-8 pale, subhyaline. Sternites 1-3 washed with smoky brown. Sternite 9 pale except for a dark brown lateral triangle based on the antero-lateral angle.

*Genitalia.* Penes and forceps base pale smoky brown. Forceps wholly white. Long joint of forceps swollen in its basal third. Penes quite similar in form to those of the eastern *basalis* Bks., but with a median longitudinal line or fold near the tip.

*Tails.* Smoky greyish brown, the extreme distal portion pale. Joinings narrowly blackish. Each segment (except those at the extreme base) is pale in its basal half, so that the tail has a distinct annulate appearance.

*Holotype*—Male imago. Taken by Mr. C. Sandoz in Murray Co., Oklahoma, March 20, 1932. No. 1269.1 in the Cornell University collection.

*Paratype*—Male imago. Same data. No. 1269.3 in the Cornell collection.

*Choroterpes ferruginea*, sp. nov.

*Size.* Body  $5\frac{1}{2}$  mm.; wing 6 mm.

*General appearance.* A reddish brown species, with grey-brown abdomen and reddish wing bases.

*Head.* Brown above, with paler antennae.

*Thorax.* Nearly uniform reddish brown; a few blackish markings on the pleura.

*Legs.* Femora yellowish, each with a median purplish band, and shaded with reddish brown at the apex. Tibiae and tarsi whitish.

*Wings.* Subhyaline; the stigmatic area opaque white. A considerable area at the base of the fore wing, and a large portion of the hind wing, suffused with a reddish brown tint. Longitudinal veins of the costal margin pale yellowish; all other veins colorless.

*Abdomen.* Grey-brown above, becoming darker and reddish at the ends. Ventrally pale translucent except on the end segments. A very narrow mid-dorsal pale line that becomes obsolescent at the rear is overspread on segments 4 and 5 by broad pale mid-dorsal triangles. Smaller triangles are in the same position on segments 3 and 6. A continuous black line follows the lateral margin on segments 2 to 8, with a parallel interrupted pale line in the spiracular area immediately above it. Blackish submedian streaks border the mid-dorsal line on the apical segments. The posterior margins of the tergites are narrowly black, most evident at the postero-lateral angles. Sternite 9 reddish at the sides.

Forceps pale. Penes reddish. Tails white, sometimes faintly ringed with reddish brown toward the base; often wholly pale.

*Holotype*—Male imago. Collected by Prof. J. G. Needham at Wintergreen Point, Old Forge, N. Y., in August 1905, No. 1270.1 in Cornell University collection.

*Paratypes*—6 male imagoes; 3 of these collected at Old Forge, same data as the holotype; 1 taken at Juanita Island, Lake George, N. Y., on Aug. 21, 1920, and 2 taken at Commissioner's Is., Lake George, Aug. 25, 1920, by Prof. Needham. No. 1270.3-8 in the Cornell collection.

#### SUBFAMILY EPHEMERELLINAE

In the treatment of this large group, I follow Dr. McDunnough in reducing Chitonophora to Ephemerella, and considering all North American species as belonging to the one genus Ephemerella. This I subdivide into groups, as does Dr. McDunnough, but with a few minor differences. Thus the species *needhami* McD., *septentrionalis* McD., and *aurivillii* Bngtssn., along with several new species, I am considering as members of a group distinct from *invaria* Wlk. and its immediate allies; this division I designate the *needhami* group. That unique species, *hecuba* Etn., is considered as belonging to a group of its own. Otherwise I use the same grouping of species which Dr. McDunnough employed in his recent excellent paper on the eastern species of this genus (*Canad. Ent.* 63: 30-42, 61-67, 187-197, 201-216. 1931).

*Ephemerella glacialis*, sp. nov.

1884—Eaton—Revis. Monogr., p. 131; figs. 11–15, Pl. 38 (as Nymph No. 2). Wash. Terr.

1930—Walley—Canad. Ent. 62: 17 (in discussion of *E. grandis*).

This species of the *fusca* group, known only in the subimago and nymphal stages, is closely allied to *grandis* Etn., from which species it may be distinguished by the better development of the tubercles on the occiput, lateral margin of the pronotum, and on the mesothorax.

## Nymph

*Size.* Body 14–15 mm.; tails 8–10 mm.

*General color.* Mature specimens deep blackish brown, usually with a pale mid-dorsal stripe the length of the body. Immature forms are lighter brown with numerous pale markings.

*Head.* No frontal shelf nor true frontal horns. Roughened around the ocelli and bases of antennae. Occipital tubercles quite prominent, conic, directed backward.

*Thorax.* Submarginal pronotal tubercles larger than in *grandis*; in the antero-lateral angle is another small spine. Anterior submedian tubercle larger than the posterior ones; of these, one is very small and lies near the median line, the other is larger and laterad of the anterior spine. Anterior median mesothoracic tubercles much as in *grandis*. The submedian pair are well developed (in *grandis* there is an elevated submedian ridge only); median posterior tubercle larger than in *grandis*.

*Legs.* Anterior margin of fore femur unmodified by teeth or spines. Legs much as in *grandis*, but slightly more slender, especially the middle and hind tarsi. 6 to 7 denticles on each claw. Femora unicolorous in mature specimens; banded with pale areas in immature forms. Tibiae with pale basal and apical bands, the latter more prominent. Tarsi pale in the apical half.

*Abdomen.* Gills borne on segments 3–7. Lateral margins of the abdominal segments very much as in *grandis*. Dorsal spines also very similar to that species, but those on tergites 8 and 9 are slightly longer relatively. Some specimens are unicolorous dorsally; most have a wide pale mid-dorsal stripe between the rows of spines. Ventrally almost unicolorous brownish black in mature form.

*Tails.* Blackish brown at the base; beyond this, alternating pale and dark areas, the pale areas more extensive.

## Female subimago

Vertex of head yellowish, with rather extensive reddish brown shading centrally and next to the eyes.

*Thorax.* Mesonotum shiny blackish brown. Pleura and sternum paler brown, the latter shaded with grey. A pale area anterior to the wing root contains a purplish red streak; a purplish line margins the anterior portion of the mesonotum, and similarly colored areas are present on the pleura. Femora dull reddish brown; tibiae greyed brown; tarsi blackish. Wings pale greyish; venation purplish black.

*Abdomen.* Blackish, the posterior margins of all segments pale, producing an annulate appearance. Tails blackish brown.

Holotype—Female nymph. Collected by Prof. A. S. Hazzard and others (J. E. H., M. J. M.) in Glacier National Park, Mont., Midvale Creek, June 8, 1932. No. 1262.1 in the Cornell University collection.

Paratypes—1 female subimago (with nymph slough), Cayoosh Creek, Seton Lake, B. C., July 31, 1933; reared by Dr. J. McDunnough; 2 mature nymphs, same data, collector, Dr. McDunnough; 22 nymphs, Glacier National Park, June 8–9, and June 16, 1932; collector, Prof. Hazzard and others. No. 1262.3–27 in the Cornell collection. (Female subimago and nymphs taken by Dr. McDunnough are in the Canadian National Collection.)

*Ephemerella doris*, sp. nov.

A species of the *bicolor* group, rather close to *temporalis* McD. Imago with a curved row of dark spots on the venter of the abdomen, a small black spot at the apex of each coxa, and blackish submedian abdominal streaks. Nymph with the postero-lateral spine on segment 3 considerably longer than its width at base; dorsal spines subparallel; distance between spines on 5–7 less than the length of these segments at the median line.

Male imago (incompletely freed from subimaginal skin)

*Size.* Body 7 mm.; wing  $7\frac{1}{2}$  mm.

*Head.* Eyes orange. Base of antenna pale, the filament brownish. A dark spot below the antenna, at the corner of each eye.

*Thorax.* Yellowish brown. A few black dots on the pronotum. *Metanotum*, and the lateral areas below the mesoscutellum, reddish

brown. A black spot on each side of the median line, on the metanotum. Mesothoracic ganglion black margined.

*Legs.* Pale yellowish. A small black spot on each coxa, near the apex. Claws, tarsal joinings, and the apex of the fore tibia light reddish brown.

*Wings.* Hyaline; venation hyaline. A short dark streak along the costa and radius of the fore wing, near the base; faint brownish tinge at base in the anal region. Stigmatic cross veins anastomosed.

*Abdomen.* Yellowish. The posterior margins of the basal and middle tergites are reddish brown. Distinct black submedian streaks are present on tergites 2, 3, and 6-7; slight indications of these on the other tergites. A small black spot on each side of the median line at the anterior margin, on tergites 8 and 9; tergite 10 wholly whitish. A dusky line follows the course of the main longitudinal trachea on each side; between it and the pleural fold are incomplete black streaks in the stigmatic area. Ventrally pale; a very narrow black line near the posterior margin of each basal and middle sternite. Four dark marks cross each sternite in a somewhat curved line; these consist of a short oblique submedian streak on the anterior margin, and a central dot, on each side. Ganglionic areas black-margined.

*Tails.* Pale. Joinings distinct, purplish black.

*Genitalia.* Of the type usual for this group..

### Nymph

*Size.* Body 7-8½ mm.; tails 5-6 mm.

*General color.* In one color phase, marked conspicuously with alternate areas of blackish brown and cream-white.

*Head.* Antennae, occiput, and a small area anterior to each ocellus, pale whitish. Remainder dark reddish brown. Occipital tubercles rounded, quite well developed in both sexes.

*Thorax.* Lateral margin of pronotum concave; its antero-lateral angle acute, projecting slightly. Pronotum yellowish brown laterally, pale in the median area, which is margined by dark brown somewhat oblique bands. Mesonotum dark brown across the anterior margin and in a median triangular area just behind the margin; within this dark band are small pale spots, one median and two lateral in position. Another dark transverse band crosses the posterior margin and passes behind the bases of the wing buds. The intervening area is pale cream-colored, with one small dark brown dot on each side.

*Legs.* Yellowish brown. Femora somewhat flattened and relatively



wide, often with pale median mottling and pale at the apex. Tibiae with a dark median band; tarsi dark-banded at the base; tip of claw dark brown. Fore femur only twice as long as wide.

*Abdomen.* Tergites 1, 4, 5, and 8 are largely pale; remaining tergites largely dark reddish to blackish brown, with a sprinkling of pale dots. Indications of black submedian stripes, which on the pale tergites are represented by black areas on the anterior margins only; laterad of each of these dark spots is usually another dark patch. Tips of the postero-lateral spines and bases of the lateral extensions pale, a brownish band between. Bases of the operculate gills blackish brown, sprinkled with pale dots. Postero-lateral spines well developed on segments 2-9; short but distinct on segment 2; on 3, almost twice as long as its width at the base. Spines on 4-7 long and slender; on 8 and 9 wider. Outer margin of segment 9 convex, the spine straight. Dorsal abdominal spines on tergites 1-3 quite long, blunt, somewhat finger-like, sloping backwards. On 4-7 more flattened than on the basal segments, as is usual in this group. Very short, but present, on 8 and 9. The spines of each pair on tergites 1-3 diverge slightly at the tip. However, the rows of spines lie parallel to each other. The distance between the spines on tergites 5-7 is less than the length of these tergites at the middle line. Ventrally yellowish, with a series of dark lateral streaks on each side. The usual curved row of dark dots is more or less evident.

Two of the specimens included in the paratypes are almost wholly reddish brown, showing none of the conspicuous alternation of light and dark areas so marked in all the other nymphs. Other specimens are brownish with dark markings, and a wide pale dorsal line the length of the body.

*Tails.* Yellowish. One or two dark rings near the base; beyond this, rather indistinct bands of pale brown alternate with the yellow.

*Holotype*—Male imago, reared from nymph. Collected by J. R. Traver on the Uharie River near Farmer, North Carolina, May 6, 1929. No. 1292.1 in the Cornell University collection.

*Paratypes*—5 male and 4 female nymphs, Withlacoochee River, near Macon, Georgia, March 21-22, 1931; collector, Prof. P. W. Fattig; 1 male and 1 female nymph, outlet of Lake Waccamaw, N. C., April 11, 1929; collector, Prof. J. G. Needham. No. 1292.-3-13 in the Cornell collection.

We have other specimens of this species, representing the three apparent color phases, from Withlacoochee River, Georgia, and a single nymph

from the Neuse River near Ft. Barnwell, N. C., taken on April 9, 1930. The species, while quite close to *temporalis* McD., may be separated from that species in the nymphal stage by (1) its smaller size; (2) the distinct concavity of the outer margin of the prothorax; (3) the greater width of the femora in proportion to their length; and (4) the fact that the lateral extensions of segments 5-7 are distinctly narrower at the base than is the case in *temporalis*. The postero-lateral spine on segment 3 is likewise slightly longer and more outcurved than in *temporalis*. The dorsal spines on tergites 1-3 are slightly narrower at the base, in *doris*, but wider and blunter at the tips; those on 8 and 9, while very small, are still better developed than in *temporalis*.

*Ephemerella angusta*, sp. nov.

A slender species apparently allied to the members of the *needhami* group; head and thorax smooth; dorsal spines present; lateral extensions of the abdomen inconspicuous; known in the nymphal stage only.

Nymph

*Size.* Body 7-8 mm.; tails 4-5 mm.

*General color.* Light reddish brown (alcoholic specimens).

*Head.* Smooth. Antennae pale. Canines of the mandibles rather well developed. Maxillary palp rather weak, but composed of three complete joints.

*Thorax.* Smooth. No definite markings in any of the specimens examined. In mature nymphs, the wing pads and the portion of the mesonotum immediately anterior to them are dark brown.

*Legs.* Pale, apparently not banded. Rather long and slender, especially those of the hind pair, which are fully as long as the abdomen. Short spines on the posterior margins of the femora, and a few on the upper surface of the fore femur, near the apex. 6 to 7 denticles on each claw.

*Abdomen.* Relatively long and slender; the basal and apical segments narrow, the middle ones slightly wider. Lateral extensions inconspicuous. Short postero-lateral spines present on segments 4-9. Gills borne on segments 3-7. Dorsal spines present on segments 2-8; short and inconspicuous on tergites 2 and 3, well developed on 5-7. Anterior margin of each tergite pale, the remaining portion reddish brown; the posterior margins may be narrowly darker. Pleural margin narrowly brown; a dark spot at the insertion of each pair of gills. Dark

lateral patches may be present on the middle segments, next to the gills. No definite ventral markings.

*Tails.* Yellow to yellowish brown. In mature nymphs, marked at the base with incomplete dark rings, apparently due to the tail of the enclosed subimago. Practically bare at base and tip; in the middle area, a few short spines at the joinings.

*Holotype*—Female nymph. Collected by Prof. J. G. Needham on Provo River, Utah, near Deer Creek, July 29, 1926. No. 1290.1 in the Cornell University collection.

*Paratypes*—3 male and 1 female nymph, same data; 2 male nymphs, North Fork of the Ogden River, Utah, July 27, 1926; same collector. No. 1290.3–8 in the Cornell collection.

We have also several immature nymphs of this species from the Yellowstone National Park, taken by Mr. J. T. Needham in 1921, and two others from the same locality, taken by Dr. Muttkowski in August 1922.

*Ephemerella hystrix*, sp. nov.

A species of the *needhami* group, known only in the nymphal stage. Long slender divergent spines present on abdominal segments 2–9.

Nymph

*Size.* Body 10 mm.; tails missing.

*General color.* Light reddish brown.

*Head.* Smooth, without horns or tubercles. Mandible almost straight on the outer margin. Canines moderately stout, rather short, tips rounded. Galea of maxilla conical; the three joints of the palp subequal one to the other.

*Thorax.* Smooth; without tubercles. A few irregular pale markings on each side of the pronotum.

*Legs.* Fore and middle leg missing. Hind femur slightly flattened; 10 to 12 spines and numerous rather long hairs on its posterior margin. Somewhat longer hairs along the posterior margin of the tibia, shorter ones on the tarsus; the latter has also a series of spines on the anterior margin. Claw rather stout at the base, the tip distinctly curved; 7 to 8 denticles on its inner margin. All joinings, the distal end of the tarsus, and the claw, dark reddish brown. One small dark spot on each coxa; two near the apical margin of each trochanter; no other markings.

*Abdomen.* Gills present on segments 3–7. Long slender spines, curved near the tips, present on tergites 2–9. Each spine bears a

series of spinules near its tip, on the anterior margin. Spines on tergite 2 are shorter than the following pairs; quite close together near the median line; slightly longer than the length of the tergite at the median line. The spines on the succeeding tergites gradually increase in length to the 5th pair, on tergite 6; spines on 6 and 7 about equal in length; those on 8 and 9 slightly shorter, subequal to each other. On tergites 3-7 the spines of each pair are progressively divergent; on 2 and 3, these are directed backward, while spines on 4-7 show a progressive tendency to turn outward as well as backward; the pair on tergite 7 are most widely divergent. On tergite 8, the spines are closer together than on 7; on 9, closer together than on 8. Spines on these last tergites are slightly stouter and less curved at the tips; those on 9 tend to be horizontal rather than erect. Gills pale. Basal tergites pale reddish brown in color, becoming progressively darker toward the apex; tergite 9 very dark red-brown. A median dark stripe between the spines on tergites 7 and 8; traces of dark submedian streaks on the preceding tergites. Large dark reddish brown patches beneath the gills and on tergites 8 and 9. Short lateral extensions of the abdomen are present, which bear short postero-lateral spines on segments 4-7. Postero-lateral angles of segments 8 and 9 somewhat incurved, rounded.

Venter pale reddish basally; sternite 9 almost wholly dark red-brown. Each sternite is marked with a broad lateral triangle of dark red-brown, within each of which is a darker oblique submedian streak. These triangles, on the middle and apical sternites, are connected by a dark transverse bar across the anterior margin. Ganglionic areas pale with dark outlines on sternites 1-6; on 7-8, dark brown.

*Tails.* Missing.

Holotype—Female nymph. Collected by Mr. Frank T. Barry on Big Blackfoot River, Potomac, Montana, June 29, 1906.  
No. 1287.1 in the Cornell University collection.

This is the species briefly described, but not named, by Prof. J. G. Needham in his paper on the Rocky Mountain species of *Ephemerella* (Ann. Ent. Soc. Amer. 20: 116, 1927).

*Ephemerella euterpe*, sp. nov.

A species of the *needhami* group. Genitalia without spines; venation light reddish brown; prominent dark ventral markings. Nymph without dorsal spines.

## Male imago

*Size.* Body 10–11 mm.; wing 10–11 mm.; tails  $10\frac{1}{2}$ – $11\frac{1}{2}$  mm.

*Head.* Dark brown, paler on frontal margin and at bases of antennae. Antennae light brown. Eyes probably light orange, in life.

*Thorax.* Reddish brown. Pronotum shaded with smoky brown. Mesonotum margined with darker brown; narrow darker brown median and submedian streaks on the scutum, and a very narrow black line along the lateral margin. A dark transverse streak on the praescutum. Mesonotal scutellum outlined with black, its lateral margins dark red-brown. A pale area on each side of the scutum near the anterior margin of the scutellum. Metanotum dark brown. Two dark brown streaks on the pleura, one anterior to each leg; intersegmental spaces yellowish. Prosternum, the portion of the mesosternum anterior to the middle leg, and a dark anterior and lateral margin around the middle sclerite of the mesosternum, dark red-brown. Remainder of sternum light reddish brown. Ganglionic areas blackish.

*Legs.*—Yellowish. Apical margin of fore trochanter, a narrow line on the edge of the fore femur, and a small spot near its apex, reddish brown. Fore femur faintly tinged with smoky at base and apex. Distal joint of fore tarsus, and claw, smoky. Very small spines on the fore tibia. Claws and tarsal joinings of middle and hind legs pale smoky.

*Wings.* Hyaline. Stigmatic area opaque whitish, the cross veins anastomosed near the costal margin. Longitudinal veins light reddish brown except those of the anal area which are wholly pale. Cross veins pale, indistinct.

*Abdomen.* Light reddish to olive brown dorsally, the apical segments darker brown. Anterior margins narrowly dark, posterior margins pale. Pleural fold pale. A narrow dark line parallels the pleural fold in the stigmatic region; a dark dot at the stigma, a dark line near the anterior margin, and near the center a small pale oblong area outlined in dark brown. Traces of a pale median line and of pale submedian streaks on the basal tergites. Ventrally pale yellowish white with deep purplish brown markings, in the form of lateral triangles based on the anterior margin and extending laterally almost to the posterior margin. On sternite 1, and 7–9, this dark area is continuous across the anterior margin; on the middle segments the triangles are not united. Sternites 7–9 largely dark. Ganglionic areas blackish brown.

*Tails.* Dark purplish brown basally, paler distally. Joinings not distinct.

*Genitalia.* Reddish brown. Second joint of forceps slightly bowed; somewhat enlarged basally, and apically on the outer margin only. Terminal joint short, thick, conical. Penes united except at the apex, where a V-shaped cleft separates them; no spines are present.

#### Female imago

Head and thorax greyish yellow. Legs somewhat paler than in the male. Cross veins of wings very faintly indicated. Abdomen purplish grey dorsally when filled with eggs. Ventral markings reddish purple; tendency for the dark lateral triangles to be united along the anterior margin. Subanal plate pale. Tails as in the male.

Some of the paratypes have a distinctly purplish red wash on head, thorax, legs, and abdomen. The allotype, described above, lacks this reddish tinge.

#### Nymph

*Size.* Body 10–11 mm.; tails 5 mm.

*General color.* Light reddish brown.

*Head.* Smooth, without horns or tubercles. Genae produced laterally as in *maculata*, forming a frontal shelf which overhangs the mouth-parts. Antennae dark reddish brown at base, paler distally. Maxillary palp as in *maculata*. Canines moderately long, tips rather blunt. Galea of maxilla rather stout, both margins rounded out, a crown of long hairs at the tip on the upper margin; 2 long stout spines and several more slender ones at tip on the inner margin.

*Thorax.* Much as in *maculata*. A few indistinct dark brown markings on each side of the pronotum and anterior to the wing roots on the mesonotum. Ganglionic areas darkened on sternum.

*Legs.* Femora without tubercles; only a few short spines along each margin. Legs fringed with hairs as in *maculata*. Tips of femora and tibiae, both ends of the tarsi, and claws, dark reddish brown. 4 or 5 denticles on each claw, near the middle of the inner margin. Ventrally a small reddish brown spot at the apex of the trochanter, near the anterior margin.

*Abdomen.* Gills borne on segments 3–7, sometimes reddish in color. Lateral extensions of the abdominal segments quite prominent; each produced into a postero-lateral spine. No dorsal spines. Apical tergites distinctly reddish. Ventrally marked with broad lateral triangles as in the imago, which are distinctly reddish in color, and often connected along the anterior margin. Ganglionic areas darkened.

*Tails.* Blackish brown at base, becoming pale reddish brown distally. Two or three narrow dark bands cross each tail near the base. Except in the basal third, each tail is fringed with rather long hairs.

*Holotype*—Male imago. Collected by Dr. David Shepherd on Waddell Creek, Rancho del Oso, Calif. No. 1286.1 in the Cornell University collection.

*Allotype*—Female imago. Same data. No. 1286.2 in the Cornell University collection.

*Paratypes*—1 male imago; 7 female imagoes, one reared from the nymph; 1 male subimago; 2 female subimagoes; 3 nymphs. Same data as holotype. No. 1286.3-12 in the Cornell collection, 1 male, 2 females, 1 nymph, in the Stanford University collection.

*Ephemerella maculata*, sp. nov.

A member of the *needhami* group. Genitalia of male without spines; venation dark purplish brown. Nymph without dorsal spines.

Male imago

*Size.* Body 8 mm.; wing 8 mm.

*Head.* Blackish brown; frontal margin translucent, pale. Antennae deep smoky brown. Eyes dull orange.

*Thorax.* Very dark olive brown. Mesonotal scutellum and its lateral margins, the lateral margins of the mesonotum, and most of the sternum, blackish brown; the latter paler around the bases of the legs. Ganglionic areas distinctly blackish. Pleura dark brown, the intersegmental spaces yellowish.

*Legs.* Fore femur yellowish at the base, brown at apex; tibia deep olive brown; tarsus paler smoky brown. Middle and hind legs yellowish white; blackish pencillings on the femora at base and apex; tibiae shaded with brown at base; tarsi pale smoky brown.

*Wings.* Hyaline. Longitudinal veins dark purplish brown, cross veins of the fore wing finer but distinctly dark. A dark reddish brown spot is present at the base of the subcosta and radius of both fore and hind wings, and a dark streak at the base of the anal region of the fore wing. Stigmatic area opaque whitish, the cross veins anastomosed.

*Abdomen.* Smoky to olive brown dorsally; tergites 1-2 and 7-8 washed with blackish brown; middle tergites shaded with reddish brown medially. A dark brown line is present on each tergite just above the pale pleural fold; a brown crescentic mark lies on this line near the ante-

rior margin, and a darker spot at the stigma. Two or three small rounded pale areas may lie on each side of this dark line, on the middle tergites. Tergite 9 washed with reddish brown in its posterior half; base of tergite 9, and most of 10, yellowish. Posterior margins of tergites narrowly pale. Ventrally pale yellowish white with prominent brownish black markings. On sternites 1-7, these consist of a wide dark anterior margin, from which lateral extensions reach backward almost to the posterior margin; ganglionic areas blackish. Sternites 8 and 9 largely brownish black.

*Tails.* Missing, from the single male imago available. In a nearly mature male subimago, black at the base, becoming deep brown distally.

*Genitalia.* Dark smoky brown. Second joint of forceps somewhat bowed; slightly swollen at the base and apically on the outer margin only. Third joint short, stout, rounded. The penes are united for two-thirds of their length; at the apex a wide V-shaped cleft separates them. The entire structure is roughly hour-glass-shaped.

#### Female imago

*Head.* Yellowish brown.

*Thorax.* Notum paler than in the male,—reddish brown with yellow shading. Pronotum greyish brown. Fore leg reddish brown, the last tarsal joint paler. Femora of middle and hind legs tinged with yellowish red, the tarsi smoky except the distal joint, which is pale. Wings as in the male.

*Abdomen.* Blackish brown when filled with eggs. Tergites marked with reddish brown above the pleural fold. Venter as in the male. Subanal plate yellow apically. Tails blackish at the base, deep smoky brown distally; joinings indistinctly darker.

#### Nymph

*Size.* Body of male, 7 mm., of female, 9 mm.; tails 4-5 mm.

*General color.* Yellowish to pale yellowish brown, with brown markings.

*Head.* Smooth, without frontal horns or occipital tubercles. Genae produced laterally and anteriorly below the antennae, so that the frontal margin appears as a square-cornered shelf overhanging the mouthparts. Maxillary palp well developed, dark brown distally; the basal joint long and constricted near the middle, appearing to be composed of two joints; second joint short, third almost as long as the first, and tapering distally. Canines quite long and sharp-pointed.



*Thorax.* Antero-lateral angles of the pronotum produced forward. An indentation on the front margin near the lateral angle, on each side; front margin convex. Thorax without spines or tubercles (one female nymph examined possessed a short lateral tubercle on only one side of the pronotum). Dark brown spots and pencillings on each side of the pronotum, and on the mesonotum between and anterior to the wing pads, and on the anterior margin.

*Legs.* Yellowish white. Femora moderately flattened, without tubercles or spines, but with fringes of long hairs on the posterior margin. Tibiae likewise fringed on the posterior margin. Tibia marked narrowly at each end with dark reddish brown; apex of tarsus and tip of claw dark red. 3 to 4 short blunt denticles on each claw at about the middle of the inner margin.

*Abdomen.* Abdominal segments 2-9 with quite well developed lateral extensions, each bearing a postero-lateral spine; spines on 2-7 rather short, long on 8 and 9. No dorsal spines. Tergites 1-2, 5-6, and the median and lateral areas of 7, shaded with reddish brown, which is darkest laterally, forming distinct dark patches. Gills borne on segments 3-7. A black spot at the insertion of each gill. Ventrally yellowish, with brownish black bands on the anterior margins and lateral extensions backward from these, as in the imago. Ganglionic areas darkened.

*Tails.* Pale yellowish white, the extreme tips dark brown (in fully mature nymphs, the bases are also dark brown). Each is marked near the base by two dark reddish brown cross bands. Hairs short and few near the base; beyond the basal third, each tail is well fringed.

*Holotype*—Male imago. Collected by Mr. Charles D. Michener in San Gabriel Canyon, San Gabriel Mts., Calif., June 9, 1932. No. 1284.1 in the Cornell University collection.

*Allotype*—Female imago. Same data. No. 1284.2 in the Cornell collection.

*Paratypes*—1 female imago, 1 male and 1 female subimago, same locality, May 24, 1932; collected by C. D. Michener. 1 female subimago, reared, Waddell Creek, Rancho del Oso, Calif.; collected by Dr. David Shepherd. No. 1284.3-6 in the Cornell collection.

Nymphs of this species were collected at San Gabriel Canyon by Mr. Charles Michener on May 23, 1931, but none were reared. However, several subimagos were reared by Dr. Shepherd from similar nymphs taken at Waddell Creek, thus associating the nymph and adult stage.

We have also two nymphs taken at San Antonio Canyon, Calif., on May 23, 1923, by Prof. J. G. Needham.

The wings of the subimago are pale smoky brown with a faint tinge of red.

*Ephemerella concinnata*, sp. nov.

A member of the *needhami* group, apparently close to *septentrionalis* McD., but with somewhat shorter legs. Very inconspicuous dorsal spines on the nymph, which is the only stage known.

Nymph

*Size.* Body of male 11½ mm., of female 13 mm.; tails 8½ mm.

*General color.* Dark reddish brown with a wide pale median streak almost the entire length of the body. Head, thorax, and basal abdominal segments bear numerous rather long whitish hairs.

*Head.* Smooth, without horns or tubercles. Very dark blackish brown anterior to the ocelli. Vertex and occiput yellow, with a dark brown stripe near the inner margin of each eye, these stripes connected anteriorly by a brown cross band between the eyes, forming a mark like three sides of a square. In the enclosed pale space are brown markings on each side of the median line. Antennae white at base, banded with dark brown immediately beyond; remainder yellowish white.

*Thorax.* Dark reddish brown, with indistinct small dark brown spots on each side of the pronotum and anterior to the wing roots on the mesonotum. A wide median yellowish stripe, within which are two narrow brown lines, one on each side of the very narrow pale median line, extends the entire length of the thorax dorsally. Pleura largely yellow, with brown markings. Venter yellow between the legs and along the lateral margins, the median sclerites dark red-brown.

*Legs.* Relatively long and slender, the hind leg longest; tarsus about two-thirds as long as the tibia, which is subequal to the femur. In the female, this leg is 6 mm. in length. Numerous short spines on the upper surface and along the posterior margin of each femur; longer spines on the anterior margin and apex of each tibia, and on the anterior margin of each tarsus. Numerous long hairs on the posterior margin of each joint. Femora dark brown, pale at apex, and with rather large yellow blotches at the base and near the middle on the upper surface. On the lower surface, a long curved pale streak follows the posterior margin. Tibiae yellow, with a narrow dark brown basal band and a wider dark band between the middle and the apex. Tarsus dark brown, yellowish

at each end, the apical pale band wider. Distal half of claw dark red. 8 to 9 rather long sharp denticles on each claw, those nearest the apex being longest.

*Abdomen.* Dark reddish brown dorsally, with a wide pale yellowish median streak extending to the end of the 7th tergite. Within this pale streak lies the dark median line, widest on tergites 6 and 7, narrow on the basal tergites. Rather inconspicuous dorsal spines are present on tergites 2-8, appearing as slightly raised areas on each side, upon which areas are borne numerous short dark spinules. The lateral extensions of the abdominal segments are quite prominent, each ending in a rather long postero-lateral spine. A dark brown band crosses each lateral extension near the middle of its length. Gills borne on segments 3-7; pale, each with a dark flask-shaped mark, within the basal portion of which is a pale dot. Tergites 8-10 almost wholly dark red-brown, except for the pale lateral extensions. Ventrally reddish brown with a lateral series of dark marks on each side, short oblique submedian streaks from the anterior margin, and between these and nearer the center of each sternite, two dark dots.

*Tails.* Yellow, crossed by narrow dark brown bands. At the base, two or three narrow dark bands; nearer the middle are three dark bands, each two joints in width, which occur every third or fourth joint; beyond these the tails are yellowish except for the blackish brown tip. Basally a whorl of spines is present at each joining, and occasional short hairs; beyond the middle the spines cease and rather long hairs fringe the tails on each side.

*Holotype*—Female nymph. Collected by Prof. A. S. Hazzard on Railroad Creek, Glacier National Park, Montana, June 8, 1932. No. 1285.1 in the Cornell University collection.

*Paratype*—Male nymph. Cutbank Creek, Glacier National Park, June 27, 1932. Same collector. No. 1285.3 in the Cornell collection.

This species, while seemingly quite close to the eastern *septentrionalis*, is considerably larger, and possesses also inconspicuous dorsal spines, which are lacking in the latter species.

Two smaller nymphs, taken in Glacier National Park in June 1932 by Prof. Hazzard, may be the immature stages of *concinata*, but show certain structural differences as well as differences in color pattern. The median dark brown line is wider, and margined on each side by a wide submedian yellow streak for the entire length of the body. The

lateral margin of the pronotum is widely yellow; the femora are yellow except for two narrow dark bands. Dorsal spines obsolescent. Ventral markings consist of two narrow yellow lateral lines and a partial median yellow line. For the present these nymphs are being held as a color phase of *concinata*.

*Ephemerella allegheniensis*, sp. nov.

A species of the *fuscata* group, closely allied to *tuberculata* Morgan. Known in the nymphal stage only. Body and femora flattened; numerous dorsal spines on head and thorax.

Nymph

*Size* (mature male nymph). Body  $8\frac{1}{2}$  mm.; tails 4 mm.

*General appearance.* In life, greenish brown; in alcohol, yellowish to reddish brown with black markings. A smooth-appearing nymph, with prominent dorsal spines. (Description drawn from alcoholic specimen.)

*Head.* Frontal margin notched laterally, to receive the bases of the antennae. Anterior margin of the clypeus almost straight. Very short blunt frontal horns are present. Occipital tubercles very high and prominent, much larger than in *tuberculata*. Head roughened near each ocellus. Reddish brown in color; a transverse black band extends between the eyes, and black lateral streaks on the occipital horns. Clypeus, frontal horns, and notches of the frontal shelf narrowly black-margined.

*Thorax.* A pair of rounded tubercles on the pronotum near the posterior margin, one on each side of the median line. Another pair of smaller tubercles situated on the lateral margin, between the middle and the anterior margin. A single very large mesonotal tubercle is situated between the wing roots. On each side of the mesonotum near the antero-lateral angle is a small rounded projection. The surface of the mesonotum is likewise distinctly roughened on each side of the median line and anterior to the wing roots. On the anterior margin of the mesosternum, near the median line, are two short blunt projections, and the prosternum bears a single median spine. All spines and tubercles are better developed than in *tuberculata*. Dorsum of thorax reddish brown with paler yellowish areas and black markings. Antero-lateral angles of the pronotum and an area on each side of the median line on the posterior margin, yellowish. A curved black mark on each side of the median line near the anterior margin. Posterior half of the lateral mar-

gin black. Median area of the mesonotum at the anterior margin, lateral areas just back of the antero-lateral angles, and the posterior half of the median area, pale yellowish. Black markings on the antero-lateral angles and along the anterior margin; brownish black areas anterior to the wing roots; and a wide black stripe running up each side of the prominent median tubercle, from the edges of the wing pads. Venter pale yellowish.

*Legs.* Fore femur with numerous tubercles and spines on the anterior margin, 4 to 5 spines on the posterior margin, and its upper surface bearing many small wart-like excrescences. Thumb-like process at apex of tibia well developed, blunt. Tarsus distinctly widened apically. Claw with 3 long and 1 short denticle. The middle femur bears 6-7 short teeth on the anterior margin and about 5 spines on the posterior margin; hind femur similar, but spine-like processes on the anterior margin less developed. Legs yellowish in color, indistinctly mottled and marked with brown. Femur pale apically; a pale band near the base of each tibia; fore tarsus brown at base. A small black dot is usually present on the outer anterior margin of the trochanter, ventrally.

*Abdomen.* Dorsum reddish to reddish brown, the last three tergites largely yellow. In some specimens, the anterior tergites are suffused with reddish brown. Posterior margins narrowly reddish brown. Conspicuous black lateral patches next to the gills on tergites 3-4 and 6-7, most conspicuous on tergite 4. Median line usually blackish on each tergite. Dorsal spines present on tergites 2-8; short and inconspicuous on 2 and 8, best developed on 5-7. No fringe of hairs on the posterior margins on tergites 8 and 9, as in *tuberculata*. Gills on segments 3-7, typical for the *fuscata* group. Lateral extensions on the abdominal segments 3-7 slightly more flaring than in *tuberculata*; the extension of segment 8, moreover, flares widely outward at about the middle of its length, and bears a relatively long postero-lateral spine, which is slightly incurved at its tip. Ventrally yellowish, with conspicuous black markings. These consist of a lateral row of black dashes on each side; a small black dot between these dashes and the pleural margin; short black submedian oblique dashes near the anterior margin; and a pair of black dots nearer the center of each sternite. The effect is of black lateral streaks and dots, and a curving row of four black dots between.

*Tails.* Yellowish to yellowish brown basally, becoming reddish brown at or near the middle where each is crossed by 4 or 5 narrow bands of white.

## Variations

Some of the younger nymphs show, besides the black markings described above, distinct traces of rose color in large areas on the pro- and mesonotum; the median line on the abdominal tergites and some of the lateral markings may likewise be rose colored. There is also a considerable range of variation in the relative amounts of light and dark areas on the dorsum of the body.

The paratype collected by Mr. Argo from the Potomac River is similar in all structural characters, but bears fringes of hairs on the legs. Measurements given are from this specimen, as all others are immature.

Holotype—Female nymph, partially mature. Collected by J. R. Traver on Cacapon River, W. Va., August 13, 1930. No. 1288.1 in the Cornell collection.

Paratypes—1 male nymph, mature; taken by Mr. Virgil Argo near Harper's Ferry, the Potomac River, Md.; 12 nymphs (4 males, 8 females), same data as the holotype. No. 1288.3–15 in the Cornell collection.

Most of the specimens which we have of this species were collected near the head of the Cacapon River, W. Va., after that river emerges from beneath the mountain known as Sandy Ridge. At the time of collection, I was with the members of the West Virginia University Biological Expedition. For a further account of that interesting river, the Cacapon, the reader is referred to the article by Drs. Needham and Strausbaugh (Sci. Monthly **33**: 80–85. 1931). Four nymphs were taken also by Prof. Needham at Elk Garden, W. Va., on Aug. 21, 1930.

This species, while very similar in general appearance to *tuberculata*, may be distinguished from it by (1) the greater development of the tubercles on the head and thorax, especially of the median mesonotal spine; (2) the smoother appearance of the body, which is almost lacking in hairs; (3) the widely flaring lateral margin of the 8th abdominal segment; and (4) the distinctive color pattern, particularly on the venter of the abdomen. In its habitat it is similar also to *tuberculata*, dwelling among mosses and other aquatic vegetation growing on large rocks in swift water.

*Ephemerella proserpina*, sp. nov.

A very large species of the *fuscata* group, related to *spinifera* Ndm. and *yosemite* n.sp. Known in the nymphal stage only. Occipital tubercles prominent; pronotal tubercles rather low and blunt, especially the sub-

marginal pair; dorsal spines on 8 and 9 about twice the size of those on the preceding tergites.

### Nymph

*Size.* Body 20 mm.; tails 13 mm.

*General color.* Very dark reddish brown.

*Head.* No true frontal shelf, the mouthparts projecting beyond the frontal margin. Rudiments of frontal horns faintly indicated. Head considerably roughened in the region of the ocelli. Occipital tubercles prominent. Clypeus and genae fringed with hairs.

*Thorax.* Submedian tubercles of the pronotum unequal in size; anterior one moderately large and blunt, the two posterior ones smaller, the outer of these being larger than the inner one. Submarginal tubercles much reduced, even smaller than in *yosemite*. Submedian mesonotal tubercles low and blunt; the pair near the middle of the anterior margin, and elevation laterad of these, much as in *yosemite*. A well developed median tubercle is near, but not on, the posterior margin, between the wing buds. Thorax sprinkled irregularly with fine black dots. A rather prominent median tubercle on the prosternum.

*Legs.* Anterior margin of the fore femur unmodified, without teeth or spines. Fore femur rather wide near the base; tibia and tarsus rather stout, the thumb of the tibia blunt and moderately long. Middle and hind legs relatively longer and more slender than in *yosemite*; the tibiae about one-fifth longer than the femora, which are not flattened. Legs thickly set with minute black spinules. Legs not banded. 6 to 7 denticles on each claw.

*Abdomen.* Gills present on segments 3-7; dull reddish brown, the margins pale, and with a pale basal patch. Lateral extensions and postero-lateral spines rather well developed on segments 3-9; no pale apical areas on these, as in *yosemite*. Dorsal spines prominent; present on tergites 2-9; sharp at the tips, the margins spinulate. Spines on tergite 2 erect, slightly shorter than the others. Spines on 3-7 sloping backward slightly, and increasing gradually but slightly in length from 3 to 5; those on 5-7 subequal in length. Rows of spines closest together on tergite 2; divergent on 3-5; subparallel on 6 and 7, not as far apart as on 5; divergent again on 8, convergent on 9. Spines on tergites 8 and 9 at least twice as long and large as those on the preceding tergites. Spines on 8 similar in form to preceding ones; long hairs on these spines and on the anterior median portions of tergites 8 and 9. Spine on 9 about as long as on 8, but more slender at the base; straight, and directed

backward. The lateral margin of the 9th tergite is flared slightly near the anterior border, and the postero-lateral spine tends to turn outward, as in *spinifera*. No yellowish dorsal markings, but the median area of each tergite is somewhat paler red than the lateral portions; this is most noticeable on tergite 8. Ventrally dark reddish brown like the dorsum; faint indications of lateral dark marks, and of a dark dot near the middle of the lateral margin of each sternite. Lateral extensions blackish brown.

*Tails.* Dark reddish brown, narrowly banded with yellowish except near the base; usually  $2\frac{1}{2}$  dark segments alternate with  $1\frac{1}{2}$  pale ones. A whorl of very short spines at each joining.

*Holotype*—Female nymph. Collected by Mr. Charles Michener in Mill Creek Canyon, San Bernardino Mts., Calif., April 2, 1931. No. 1294.1 in the Cornell University collection.

This species may be distinguished from its nearest ally, *yosemite*, by (1) the much greater size; (2) the inequality of the second pair of submedian tubercles on the pronotum; (3) the much lower submarginal tubercles on the pronotum; (4) the longer and more slender middle and hind legs. It may readily be separated from *spinifera* by the much greater size, the very short submarginal pronotal tubercles, and the unequal submedian tubercles of the pronotum.

*Ephemerella yosemite*, sp. nov.

A member of the *fuscata* group; related to *spinifera* Ndm. and *proserpina* n. sp. Only the nymph is known. Occipital tubercles very prominent; submedian tubercles of the pronotum unequal and blunt. Dorsal spines prominent, those on tergites 8 and 9 twice as high as on the preceding tergites.

Nymph

*Size* (specimen not yet mature). Body 13 mm.; tails 9 mm.

*General color.* Blackish brown with yellow markings.

*Head.* Occipital tubercles very prominent. No true frontal shelf, the mouthparts projecting beyond the frontal margin. Very faint indications of rudimentary frontal horns. Head roughened in the region of the ocelli. Lateral margins, median area of the frons up to the vertex, a line along the inner margin of the eye and up the occipital tubercles, and the middle of the occiput, blackish brown; remainder yellowish. Antennae black at base, dark brown beyond.



*Thorax.* Very short tubercles near the middle of the lateral margin of the pronotum, one on each side. A pair of blunt submedian tubercles slightly back of the middle of the sclerite, one on each side; posterior to these a pair of very small tubercles on each side. Submedian tubercles of the mesonotum likewise rather heavy and blunt. A pair of smaller tubercles on each side of the median line, on the anterior margin; laterad of each of these a broader tubercle-like elevation. A slight elevation of the median line at the posterior margin. Thoracic notum dark brown; tubercles, anterior margin, and the anterior median portion of the mesonotum, blackish; postero-lateral angle of the pronotum and the median posterior portion of the mesonotum yellowish; irregularly sprinkled with fine black dots. Venter yellowish brown, sprinkled with fine dark dots. A prominent median tubercle on the prosternum.

*Legs.* Anterior margin of the fore femur unmodified by teeth or spines; rather wide and thick, widest near the base. Tibia and tarsus likewise relatively thick; tibial thumb moderately long, blunt at the tip. Femora dark brown with three or four large pale areas; all are considerably flattened. Tibiae blackish, with wide yellow bands at each end. Tarsus and claw blackish; a pale brownish median band on the tarsus, and one near the base of each claw. 5 to 6 denticles on each claw. Tibiae of middle and hind legs scarcely longer than the femora. Legs thickly set with minute dark spinules.

*Abdomen.* Gills present on segments 3-7. Dorsal spines on tergites 2-9; those on 2-7 quite prominent, slanting backward slightly; pointed at the tips; subequal on 4-7, slightly shorter on 2 and 3. Spines on 8 and 9 show a sudden increase in size, being more than twice as high and correspondingly larger than those of the preceding tergites. On tergite 8 these spines are erect; on 9 they slant backward. Rows of spines divergent on 2-5; convergent on 6-7; on 8 and 9, farther apart, sub-parallel. Lateral extensions of the abdomen and the postero-lateral spines quite well developed on segments 4-9, smaller on 3. Dorsally blackish brown with a reddish tinge laterally. A large yellow patch occupies most of tergite 8; the apical portions of the lateral extensions on 4-8 are also pale, most prominently so on segment 8. Gills dark olive brown margined with whitish, and with a white patch near the base. Long hairs on the dorsal spine of segment 8 and along the median areas of tergites 8 and 9; shorter hairs on the spine of tergite 9. The lateral margin of tergite 9 is practically straight, as is the postero-lateral spine. Ventrally dull reddish brown, sprinkled with numerous fine dark dots. Posterior margins of the sternites narrowly darker. A

series of dark lateral streaks on each side, and faintly darker over the ganglionic areas.

*Tails.* Blackish brown\*, banded narrowly with yellow; usually 3 dark segments alternate with one pale one. A whorl of very short spines at each joining.

*Holotype*—Female nymph, not yet mature. Collected by Dr. P. R. Needham on Merced River, the Yosemite Valley, Calif., February 8, 1933. No. 1293.1 in the Cornell University collection.

*Paratypes*—6 immature nymphs, same data; 3 immature nymphs, Feather River, Chester, Calif., Nov. 11, 1932. Same collector. No. 1293.3-11 in the Cornell collection.

From *spinifera*, its near ally, this species may be distinguished by (1) the much larger size; (2) the blunter submedian tubercles on the pronotum, which are likewise very unequal in size; (3) the much smaller and blunter lateral pronotal tubercles; and (4), the shorter and thicker joints of the legs. From *proserpina*, to which it is most closely related, it may be separated by (1) the smaller size; (2) the slightly larger submarginal tubercles of the pronotum; (3) the very small equal paired posterior submedian tubercles of the pronotum; (4) the shorter legs and more flattened femora; and (5) the practically straight lateral margin and postero-lateral spine of segment 9.

*Ephemerella micheneri*, sp. nov.

A species of the *serrata* group, allied to *tibialis* McD.; venation pale.

Male imago

*Size.* Body 6-7 mm.; wing 7 mm.; tails 8 mm.

*Head.* Yellowish, shaded with brown around the bases of the antennae. Basal joint of antenna brown; second joint pale; filament brown. Eyes orange.

*Thorax.* Yellow, with brownish black markings. Pronotum mottled with brown. A brown transverse band and a short longitudinal streak on the pleura of the prothorax, above the fore leg. Scutum of mesonotum margined narrowly with brown, and with a narrow brown median line. Scutellum narrowly margined with brown; two median and two lateral brown streaks just anterior to the scutellum. Metanotum brownish, with two lateral dark brown streaks and three median dark dots. A purplish brown streak extends obliquely across the pleura from the wing base to the anterior margin of the prothoracic pleura. Above

and anterior to the middle and hind legs are two blackish streaks, and the coxae are black-marked. Sternum yellowish to yellowish brown, the lateral areas of the mesosternum anterior to the middle legs shaded with darker brown. The median areas of the pro- and mesosterna are outlined in black; especially prominent is the transverse black streak across the anterior margin of the mesosternum. Ganglionic areas of the meso- and metasterna are more or less distinctly darkened.

*Legs.* Yellowish. Fore tibia and tarsus pale smoky, the tibia darker than the tarsus. Fore tibia very long, as in *tibialis*; about twice the length of the femur. A narrow brownish red line near the apex of each femur, on the inner surface. Claws and basal joints of tarsi pale smoky.

*Wings.* Sub-hyaline to hyaline. Venation pale. A purplish streak extends up on to the membrane of the fore wing just below the costal margin, on the outer surface. On the inner surface, the costa and subcosta are brownish at the extreme base, the latter with a small black dot basally. Stigmatic area opaque whitish.

*Abdomen.* Brownish dorsally, yellowish ventrally. Tergites 2-8 rather heavily shaded with reddish to olive brown laterally; on the basal tergites this shading is more or less continuous across the dorsum also, while on 5-8 the median area is yellowish. Posterior margins of all segments pale. A blackish brown dot on the middle tergites, and a short streak on the basal and distal tergites, marks the stigmatic area. Pleural fold pale. Ventrally, a reddish brown streak, sometimes rather triangular, margins the pleural fold on each sternite. Ganglionic areas purplish black, the basal ones with blackish outlines and a dark median dot. Basal and middle sternites yellowish white, apical sternites yellow, sometimes marked extensively with powder white.

*Genitalia.* Yellowish amber. Forceps rather strongly bowed, the second joint enlarged basally and slightly so at the apex. Penes separated apically by a V-shaped cleft. The apical margin of each bears two or three blunt processes. A spine-like lateral process is present on each side. In lateral view, this spine projects upward.

*Tails.* White. Joinings purplish black.

#### Female imago

Head with extensive cream-white areas on the vertex and along the inner margin of each eye. Thorax with more extensive dark markings than in the male, these markings often reddish brown. Apical bands on the femora wider and darker red than in the male. Main longitudinal veins of the fore wing pale brownish. Abdomen, when filled with eggs,

dark reddish brown, without markings dorsally except the black stigmatic streaks and the pale posterior margins. Segments 8-10 yellowish brown. Tails amber at base, joinings as in the male.

### Nymph

Nymphs taken at the same time and place as the imagoes, but not reared, are marked so much like the imagoes that they are tentatively associated with them.

*Size.* Body of male,  $6\frac{1}{2}$ -7 mm., of female 7-8 mm.; tails 3-4 mm.

*General appearance.* Yellowish brown with darker brown markings

*Head.* Smooth, without tubercles or frontal horns. Maxillary palp rather well developed, the basal joint almost as long as the 2nd and 3rd combined. Canines wide, short, blunt.

*Thorax.* Smooth, without tubercles or spines. Irregular dark brown markings on each side of the pronotum, and on the mesonotum between and anterior to the wing roots. Median areas of the pro- and mesosterna outlined in black, as in the imago; the ganglionic areas distinctly dark.

*Legs.* Pale yellowish. A blackish spot at the base of the tarsus; apex of tarsus, and claw, blackish brown. Fore femur unmodified on the anterior margin; bearing only a few short spines on the upper surface and several long hairs and spines on the posterior margin. Other femora very similar. 7 to 8 denticles on each claw.

*Abdomen.* Dorsal spines present on the apical margins of tergites 2-8; short on 2 and 8, somewhat longer on 3 and 4, longest on 5-7. Abdominal segments 4-9 with short lateral extensions, of which all but segment 8 bear short blunt postero-lateral spines. Gills borne on segments 3-7. Yellowish to yellowish brown in color, the basal and middle tergites more or less shaded with black. Fully mature nymphs usually show lateral black patches on tergites 2-8; anterior margins blackish brown; and a variable amount of brown shading along the median line. Markings on tergite 8 are less distinct, consisting of a median brownish grey triangle based on the anterior margin, and occasionally a brown lateral mark. Ventrally the ganglionic areas are darkened, and a double row of lateral brown marks, each somewhat curved, is present on each side.

*Tails.* Alternately yellow and brownish black, each joining brown. Black areas close together and more numerous at the base than elsewhere. A whorl of short spines at each joining.

**Holotype**—Male imago. Collected by Mr. Charles D. Michener in San Gabriel Canyon, San Gabriel Mts., California, June 25, 1932.

No. 1283.1 in the Cornell University collection.

**Allotype**—Female imago. Same data. No. 1283.2 in Cornell collection.

**Paratypes**—10 male imagoes, 12 female imagoes, same locality, same collector; May 28, June 9, 25, and 28, and July 21 and 23, 1932. No. 1283.3–24 in the Cornell collection.

I take pleasure in naming this species for Mr. Charles Michener, who has collected many fine specimens of mayflies for the Cornell collection from the vicinity of Pasadena, Cal. Nymphs were collected by Mr. Michener at the same locality on May 23, 1931, and June 23, 1932. We have also seen three male subimagoes of this species, from the Stanford University collection, taken at Waddell Creek, Rancho del Oso, Calif., by Dr. David Shepherd.

*Ephemerella teresa*, sp. nov.

A species of the *serrata* group, seemingly close to *micheneri* n.sp. Known only in the nymphal stage; dorsal abdominal spines present; maxillary palp wanting; lateral extensions of the abdominal segments moderately well developed.

Nymph

*Size.* Body 5–7 mm.; tails 2–4 mm.

*General color.* Pale reddish brown, marked with darker brown.

*Head.* Smooth. Maxillary palp entirely wanting. Antennae pale.

*Thorax.* Smooth. Median line of pronotum elevated into a carina anteriorly; depressed posteriorly, where it is bordered by lateral carinae. Indistinct darker mottling on the pro- and mesonotum. A short black mark behind each leg, on the pleura. Ganglia of the sternum dark, very distinct in most specimens; often a dark transverse line along the anterior margin of each division of the sternum, especially prominent on the mesosternum, from which short lateral lines may extend backward.

*Legs.* Pale. The usual spines are present on the upper surface of the fore femur and along the posterior margins of all the femora. Tips of tarsi, tibiae, and claws reddish brown. 9–10 denticles on each claw.

*Wing pads.* In mature nymphs, a prominent purplish line is often seen on the developing wing, close to and paralleling the costal margin.

The main longitudinal veins of the middle area of the fore wing may also be indicated by narrow dark lines.

*Abdomen.* Lateral extensions only moderately developed on the basal and middle segments, well developed on segments 8 and 9; postero-lateral spines on segments 4-9, the margins serrate. Dorsal spines present on tergites 4-7; short and farthest apart on 4, somewhat longer and subequal on 5-7, slightly convergent apically. Each bears minute spinules. Gills present on segments 3-7; purplish in color; a dark spot at the insertion of the first gill. Tergites narrowly dark brown on the posterior margins, round black lateral spots on tergites 2 and 3. Frequently larger reddish brown lateral patches are present next to the gills on segments 4-8, and small dark spots on tergite 9. On the holotype, the dark lateral areas are coalescent across the dorsum of tergites 4-8, forming a dark median blotch on each; dark median marks are also present on the basal tergites and on 9. Ventrally yellowish, with a more or less distinct series of dark lateral marks as in *serrata*; the ganglionic areas may also be darkened.

*Tails.* Pale yellowish, with whorls of dark reddish brown spines at each joining. At the base, one or two joinings may be faintly brownish.

Holotype—Male nymph. Collected by Mrs. Theresa R. Seemann in San Antonio Canyon, Calif., May 29, 1923. No. 1289.1 in the Cornell University collection.

Paratypes—3 female and 2 male nymphs, same data; 2 female nymphs, same location, same collector, May 12, 1923. No. 1289.3-9 in the Cornell collection.

This species I name in honor of Mrs. Theresa R. Seemann, who collected the specimens. It is close to *micheneri*, but may be distinguished from the latter species by the absence of the maxillary palp, the better development of the postero-lateral spines on segments 8 and 9, and by the less conspicuous dorsal spines.

*Ephemerella cognata*, sp. nov.

A member of the *serrata* group; known in the nymphal stage and female subimago only. Rather close to *tibialis* McD., but possessing distinct dorsal spines. Maxillary palp vestigial.

Nymph

*Size.* Body of female, 7-8 mm.; tails  $4\frac{1}{2}$  mm.

*General color.* Dark reddish brown.

*Head.* Smooth, without horns or tubercles. Mandibles well developed; outer margin almost straight. Canines quite large; relatively long and broad, the tips acute. Galea of maxilla conical; many long hairs at the tip on the outer margin; 2 long spines and several bristles near the apex on the inner margin. Maxillary palp represented only by a minute stub.

*Thorax.* Without spines or tubercles; however, on each side of the pronotum near the center of the posterior margin is a slight rounded elevation.

*Legs.* Femora somewhat flattened, anterior margins unmodified. On the posterior margin of each, and on the upper surface of the fore femur near the apex, are several rather long spines. Hairs on the posterior margins of the tibiae and tarsi; in addition, the hind tibia bears spines on each margin. Claws slightly curved at the tip; each bears 9 to 10 rather long sharp denticles on the inner margin. Apex of tibia and a median band on the tarsus pale; remainder of each leg reddish brown.

*Abdomen.* Gills present on segments 3-7; greyish lavender in color. Lateral extensions on segments 4-9 better developed than in *tibialis*; the margins serrate. Each is produced into a postero-lateral spine, best developed on segments 8 and 9. True dorsal spines are present on tergites 4-7; on tergite 4 these are slightly wider apart than on the following segments. Short spinules are borne on the spines of tergites 6 and 7; slightly larger spinules fringe the posterior margins of tergites 1-3 and 8-9, on each side of the median line. On tergite 3, the posterior margin is extended very slightly in the areas usually occupied by spines. Tergites dark reddish brown; indications of a darker median line and of dark lateral patches. Lateral extensions yellowish. Ventrally dark reddish brown. Markings consist of a series of black lateral streaks and indistinct darker blotches in the ganglionic areas.

*Tails.* Yellowish at base; alternate bands of brown and yellow are present beyond the middle. A whorl of spines at each joining.

#### Female subimago

Body greyish. A dark mark on the mesothoracic pleura anterior to the middle leg. Mesonotum margined laterally with deep chestnut brown. Wings very pale smoky. No distinct markings on the legs. Black lateral marks on the venter of the abdomen, as in the nymph; ganglionic areas faintly darker on sternites 1-7. On the middle sternites, traces of dark oblique submedian streaks at the anterior margins,

and of short curved marks nearer the center of each sclerite. Sternites 8 and 9 wholly pale. Tails white, joinings purplish black.

**Holotype**—Female nymph. Collected by Dr. David Shepherd on Waddell Creek, Rancho del Oso, Calif. No. 1291.1 in the Cornell University collection.

**Paratypes**—4 female nymphs; 1 female subimago, reared from nymph; same data as holotype. No. 1291.3–5 in the Cornell University collection (2 nymphs in the Stanford University collection).

We have also a single female nymph from San Antonio Canyon, Calif., June 11, 1923, collected by Prof. J. G. Needham, which seems to be of this species, but is slightly smaller than the nymphs from Waddell Creek.

#### SUBFAMILY SIPHLONURINAE

##### *Siphonurus spectabilis*, sp. nov.

**Size.** Body of male imago, 14 mm.; of female, 15–16 mm.: wing of male, 13 mm.; of female, 15–16 mm.: tails of male and female, 18 mm.

**General appearance.** Recognizable by the brown patch at the bulla of the fore wing and on the radial fork of the hind wing, and by the margined cross veins. Differs from other species of this genus in the structure of the male genitalia, and the shape of the apical margin of the subanal plate of the female. Hind wing of male tinged with orange.

#### Male imago

**Head.** Whitish. A wide purplish brown band extends across the median carina, leaving as pale areas a very narrow frontal margin and a wide band below the ocelli. Ocelli ringed with purplish black. Basal joint of antenna grey in its distal half, white basally; filament white. Eyes bluish grey above, black in lower portion. No oblique colored band across the eye.

**Thorax.** Yellowish brown marked with reddish brown. Lateral and anterior margins of mesonotum reddish brown. A wide purplish streak anterior to the wing roots. A reddish brown streak on the pleura, extending obliquely forward and downward from the fore wing, anterior to the middle leg. A reddish brown patch on the middle and hind coxae; fore coxa marked by two black longitudinal streaks. Purplish markings on the prosternum and a transverse band on the mesonotum between the middle legs.

**Legs.** Fore leg shorter than body. Legs whitish. Fore femur and



tibia, and trochanters of all legs, washed with yellowish. Fore femur narrowly reddish brown at the apex; tibio-tarsal joining reddish brown; all other joinings pale.

*Wings.* Subhyaline. Veins dark reddish brown; humeral cross vein very heavy and dark. Stigmatic area opaque whitish; cross veins mostly straight, showing a slight tendency to fork and anastomose. These veins about 18 in number; about 8 costals before the bulla. In the fore wing, the cross veins of the costal space before the bulla, and all cross veins of subcostal and radial spaces except at the apical margin, rather widely margined with dark reddish brown. At the bulla, 3 or 4 cross veins in the subcostal space are more widely margined, sometimes almost connected by the resulting brown clouds. In the radial space directly below them, a continuous dark brown blotch covers four cross veins, completely filling that portion of the space. A dark triangle partially fills the fork of the radial sector lying directly below this wide dark blotch. Some cross veins in the disc of the wing likewise narrowly margined. Anal region distinctly yellowish at the wing base, with two purplish grey streaks running out on the large veins. Cross veins of fore wing less numerous than is usual in this genus, and tending to be arranged in several series across the wing.

Hind wing distinctly tinged with yellowish orange, most noticeable in the apical portion. Several cross veins in the disc, and in several of the radial spaces beyond the radial fork, narrowly margined. In the radial space and the space of the first radial sector is a prominent dark brown wedge-shaped mark, beginning at the first fork of the sector and extending apically over four cross veins, completely filling these two spaces. Wing faintly purplish grey at the extreme base. Widened in the anal region, in this respect more like *Parametetus* than *Siphonurus*.

*Abdomen.* Yellowish white with brown markings. Posterior margins and median areas of tergites faintly washed with brown. The usual dark lateral triangles are much reduced in extent, being restricted to the postero-lateral angles and the lateral margins. Oval dark submedian spots present but rather indistinct. Between these and the lateral triangles is another longitudinal streak in the anterior portion of the basal and middle tergites. Tergites 7-10 distinctly reddish brown. Anterior pale triangles distinct in the antero-lateral angle, diffuse near the median line. A postero-lateral spine present on tergite 9. Pleural fold white. Ventrally, the oblique bands are broad, deep purplish brown in color, and united anteriorly to form more or less complete dark U-marks. A pale oval area is enclosed by each dark band on each

side, near the anterior margin. No dark dots visible within the dark U-marks. Sternite 9 entirely purplish black except for a yellowish brown lateral margin.

Forceps and forceps base purplish to purplish brown. Penes dark reddish brown. Penes somewhat resemble *alternatus* and *phyllis* in form, but have an additional long narrow forward-projecting process, reaching beyond the forceps base, which is not found in either of those species. Basal joint of forceps not clearly separated from the long joint, and entirely lacking the usual prominence on the inner margin, so that the forceps are narrowed gradually from the base. Apical margin of the forceps base between the forceps is very slightly concave at the center.

*Tails.* Dark purplish brown at base, soon shading into purplish grey, which becomes paler distally. A narrow purple streak extends forward from the base to beyond the middle, on each side of each tail. Joinings very narrowly darker in basal half.

#### Male subimago

Wings greyish. Both fore and hind wings distinctly dark grey at base of the main veins of the costal margin and in the anal region; orange tinge of hind wing not distinguishable. Tarsi smoky brown, the joinings dark reddish brown. Dorsal abdominal markings rather more distinct than in the imago. Tails darker than in imago.

#### Female imago

Posterior margin of head purplish, with faint submedian streaks extending forward on the occiput. Lateral anterior margin of pronotum reddish brown, its posterior margin purplish in the median area. Oblique purplish streaks on the pleura, between middle and hind legs. A purplish streak on the anterior margin of the fore femur at its base. Fore tibia and tarsus, and tarsi of middle and hind legs, shaded and streaked longitudinally with smoky purplish brown. Subanal plate extended backward on its apical margin into a median spine. Otherwise similar to the male imago.

#### Female subimago

Similar to male subimago.

## Nymph

Yellowish brown. Labrum and tips of mandibles and maxillae dark reddish brown. A brownish triangle below and laterad of each antenna. Pro- and mesonota with lateral reddish brown markings, also the antecoxal pieces and coxae. Legs yellowish. A brown basal and apical band on each femur; a brown basal band on each tibia; basal and apical bands on the tarsi. Wing pads clearly show the dark patches and dark veins of the imago.

Gills double on the 1st and 2nd abdominal segments only. Tergites 6 and 9 distinctly reddish brown. Each tergite with reddish brown submedian marks, ventrally reddish brown. Apical and lateral margins of all sternites whitish; a whitish submedian band on each side. Middle and apical sternites with dark reddish brown median triangles, and oblique submedian streaks in the pale bands. Laterally on the anterior margin of each is a dark brown transverse streak. Tails yellow; the usual dark band beyond the middle is orange-brown in color and rather diffuse.

Holotype—Male imago, reared from nymph. Collected by Dr. David Shepherd on Waddell Creek, Rancho del Oso, Calif. No. 1279.1 in the Cornell University collection.

Allotype—Female imago, reared. Same data. No. 1279.2 in the Cornell collection.

Paratypes—11 male subimagos, 6 female subimagos, reared; 2 nymphs; same data. No. 1279.3-13 in the Cornell collection. (4 male and 2 female subimagos in the Stanford University collection.)

*Siphonurus marshalli*, sp. nov.

Hind wing entirely stained with coffee brown, the cross veins of the disc heavily infuscated; fore wing tinged faintly with amber in the basal half, the cross veins of the disc, especially at and below the bulla, heavily infuscated. Hind tarsus barely longer than the tibia.

## Male imago

*Size.* Body 13-14 mm.; wing 13-14 mm.; tails 30-32 mm.

*General color.* Blackish brown, the abdomen paler ventrally.

*Head and thorax* deep blackish brown. Pleural sutures, an area anterior to each middle and hind leg, and a transverse band anterior to the hind legs, paler, yellowish brown. Scutellum reddish.

*Legs.* Fore femur and tibia dark reddish brown, tarsus slightly paler in color. Middle and hind legs yellowish, shaded faintly with reddish brown, especially on the tarsi and the bases of the tibiae. Hind tarsus barely longer than the tibia.

*Wings.* Fore wing tinged with amber in its basal half, the extreme base stained with brown. Cross veins of the costal and subcostal spaces, except in the stigmatic area, and in the disc of the wing, rather widely margined with dark brown. At the bulla a zigzag dark band is thus formed, three cross veins in width, and extending to the first branch of the cubitus; another small cloud is present in the radial space halfway between the bulla and the base of the wing. All veins dark brown. Hind wing entirely yellowish to coffee brown in color, slightly paler in the basal two-thirds of the costal and subcostal spaces. Cross veins of the disc, below the subcosta, are very heavily margined with dark brown, heaviest between the subcosta and median vein. A dark cloud is formed at the point where the radial sector leaves the radius, and a smaller one halfway from this to the wing margin. Subcostal veins infuscated only at the extreme base and near the apex.

*Abdomen.* Segments 1-3 and 8-10 dark reddish brown, the sternites slightly paler than the tergites, and semitranslucent. Middle segments semi-hyaline, the sternites yellowish, the tergites reddish brown with wide darker reddish brown markings. These consist of dark posterior margins, wide patches in the postero-lateral angles, and a somewhat lighter reddish brown shading on the posterior two-thirds of the central part of each tergite. Tergites 8 and 9 have yellowish antero-lateral angles. Tergite 10 is somewhat paler than 8 and 9; sternite 8 is largely deep yellow-brown except for the darker anterior margin.

*Tails.* Dark reddish brown, almost blackish at the base; tips slightly paler.

*Genitalia.* Reddish brown. Basal joint of the forceps with no extension on the inner margin. Penes appear to be somewhat of the type of *quebecensis* Prov., but differ markedly from this species in details of structure.

#### Female imago

Wing nearly 15 mm. in length. In general appearance, very similar to the male, but the abdomen is almost wholly reddish brown. Fore wing may lack the amber tinge at the base, and the brown infuscations of the cross veins in both wings are paler than in the male. Hind wing brown-tinged as in the male, but the color paler.

**Holotype**—Male imago. Collected by Mr. Byron C. Marshall at Imboden, Arkansas, April 6, 1927. No. 1299.1 in the Cornell University collection.

**Allotype**—Female imago—Same data, same collector. No. 1299.2 in the Cornell collection.

**Paratypes**—3 male imagoes and 1 female imago, April 5 and 6, 1922, and April 15, 1927; same collector. These specimens returned to Mr. Marshall. No. 1299.3–6.

This beautiful and unusual species I name in honor of Mr. Marshall, the collector.

*Ameletus shepherdii*, sp. nov.

A small species with pale whitish abdomen and amber-tinted wings.

Male imago

**Size.** Body 8 mm.; wing 8 mm.; tails 12 mm.

**Head.** Light reddish brown; frontal margin translucent amber.

**Thorax.** Light reddish brown. Mesonotum yellowish except for the reddish anterior portion, which is narrowly margined with white; scutellum pale whitish, its postero-lateral margins dark red-brown. Pleura yellowish red, with reddish brown sutures and pale whitish areas.

**Legs.** A transverse reddish brown stripe on the fore coxa. Fore leg pale amber, the femur and last three tarsal joints paler than the tibia. Tibia slightly longer than the femur. Middle and hind legs whitish, the joinings amber yellow.

**Wings.** Hyaline. Tinged distinctly with amber, especially evident on the hind wing and the stigmatic area of the fore wing. A small reddish brown spot at the base of the fore wing. Venation pale reddish brown to amber; cross veins finer than the longitudinals. Stigmatic cross veins anastomosed near the costal margin; about 8 costals beyond the bulla are straight, then follow about 12 that are anastomosed. Before the bulla are 10 to 12 costal cross veins, distinctly amber-tinged. The stigmatic area is somewhat opaque.

**Abdomen.** Segment 1 opaque, pale reddish brown. Segments 7–10, and the posterior portion of 6, opaque, yellowish red in color, rather darker dorsally. Intermediate segments pale whitish to cream colored, semi-translucent; faintly washed with pale yellowish red on the tergites, especially along the lateral borders and an indistinct band across the posterior portion. Posterior margins and ganglionic areas opaque whitish. Sternites 2 and 3 may be faintly tinged with yellowish. No distinct markings.

*Tails.* Amber-colored, paler at the tips. Joinings opaque, faintly deeper amber.

*Genitalia.* Amber-yellow. Penes somewhat resemble *cooki* McD., but the distal portions are directed outward, and a blunt thumb-like process occupies the position of the inner spine of that species. The tubercle on the inner distal margin of the forceps base is blunt and quite prominent. The apical margin is but slightly excavated.

#### Female imago

Body 9 mm., wing  $9\frac{1}{2}$  mm. Head and thorax as in male. Fore leg pale reddish brown. Tibiae and tarsi of middle and hind legs amber, femora whitish. Wings more strongly amber-tinged than in the male; venation distinctly dark reddish brown, darker than in the male. Entire dorsum of abdomen flushed with pale reddish brown, venter paler. Tails missing.

#### Male subimago

Very similar to imago. Wings greyish, but with amber tinge, at least in the later stages. Mesonotum pale whitish, with extensive lateral and anterior patches of reddish brown. Pleura paler than in the imago.

#### Nymph (from nymph slough of 1 male specimen)

Color probably pale yellowish red in life. Tarsi banded with dark reddish brown at base and apex. Abdominal segments 9 and 10 dark reddish brown; posterior margins of tergites and the narrow lateral extensions reddish brown. No other distinct markings. Postero-lateral spines present on segments 2-9; short and inconspicuous on 2, increasing gradually in length posteriorly. Tails with a wide dark red-brown band across the middle.

In size, this species is close to *cooki* McD., but differs from that species (1) in the much paler abdomen, (2) in the distinct amber tinge of the wings, and (3) in the details of the structure of the genitalia. The species is named in honor of Dr. David Shepherd, the collector.

**Holotype**—Male imago. Collected by Dr. David Shepherd on Waddell Creek, Rancho del Oso, California. Other data lacking. No. 1282.1 in the Cornell University collection.

**Allotype**—Female imago. Same data. No. 1282.2 in Cornell University collection.

**Paratypes**—5 male and 2 female subimagos. Same data. No. 1282.-3-6 in the Cornell collection. 2 males and 1 female in the Stanford collection.

*Isonychia christina*, sp. nov.

A bright red species with pale smoky brown tarsi and very pale brown venation.

## Male imago

*Size.* Body 10 mm.; wing 10 mm.; tails 20–26 mm.; fore leg 8 mm.

*Head.* Reddish. Median frontal carina and frontal margin edged with dark red; bases of antennae red, the filament reddish. Eyes reddish purple; a pale blue double transverse band on each.

*Thorax.* Very dark red. Pleura somewhat paler, usually with deep rose markings. Scutella of the meso- and metanota, and the middle of the sternum, darker red. Rose markings on the borders of the mesonotum; often a small pale spot anterior to the scutellum, and a small cream-colored area on each side of it.

*Legs.* Femur and tibia deep reddish black, femur paler basally, tibia pale at the extreme base. Tarsus pale smoky brown, usually narrowly paler at each joining; the basal third of the first joint pale whitish. Very rarely the entire tarsus is paler yellowish brown, darker at each joining. The claws are marked with deep rose. Tarsus fully as long as the tibia. Middle and hind legs yellowish white; claws and last tarsal joint faintly tinged with reddish. All coxae deep rose in color.

*Wings.* Hyaline; stigmatic area opaque white. Venation very pale brownish; each longitudinal vein is outlined by two narrow dark lines.

*Abdomen.* Intense red dorsally and ventrally, the apical segments even brighter red. Middle segments somewhat semi-translucent. Posterior margins of all segments black, wider on the tergites. Pleural fold margined with an interrupted black line; above it on the dorsum is another dark parallel line. Sternites often slightly paler at the anterior margin. Pale mid-dorsal line and darker submedian streaks almost obsolescent. On the sternites, the ganglionic area is usually rather pale, and margined by dark oblique submedian streaks.

*Tails.* White, washed with brownish red at the base; 4 to 6 of the basal joinings are usually red, all others colorless.

*Genitalia.* Forceps base reddish, deeply excavated apically. Forceps deep smoky brown, the terminal joint pale. Penes of the “albomani-cata” type; pale reddish in color.

## . Female imago

Frons of head as in male; vertex cream-colored, largely suffused with reddish. Wide reddish areas between the bases of the ocelli and in the

space between the eye and the lateral ocellus. A wide red geminate median stripe; the corners of the occiput purplish black, the posterior margin shaded with reddish. Mesonotum flesh-colored, usually with a narrow yellow median stripe anteriorly. Extensive powder-yellow markings suffused with deep rose on the borders of the mesonotum, on the pleura and on each side of the mesoscutellum. Venation very slightly darker than in the male. Tails yellowish at base, joinings as in male. Subanal plate yellowish red; rather deeply excavated apically, its outer angles acute.

### Nymph

Reddish brown, darker on the apical segments. A median white stripe, beginning on the frontal carina, extends along the thorax and continues as an interrupted line the length of the abdomen. Pale submedian streaks usually margin it on the abdominal tergites. Base of antenna pale, followed by dark brown joints near the base; pale yellowish apically. Tibial spine of fore leg about one-half as long as the tarsus; slightly outcurved apically. Claws usually with 7 denticles. Postero-lateral spine on segment 9 only slightly longer than that on segment 8. Gills pale brown, with a darker median line and anterior margin. Two diffuse darker spots on the outer margin of each.

Holotype—Male imago. Collected by Miss Christine N. Hardy, at the Balch Hall light, Ithaca, N. Y., July 24, 1931. No. 1251.1 in the Cornell University collection.

Allotype—Female imago. Same data. No. 1251.2 in the Cornell collection.

Paratypes—10 male imagoes, same data; 16 female imagoes, August 7, 1932, same locality; 6 male imagoes, June 17, 1931, same locality. All collected by Miss Hardy. No. 1251.3–34 in the Cornell collection.

Besides local material, we have specimens in the Cornell University collection, which may be of this species, from St. Lambert, Quebec, July 27, 1927, collected by Mr. G. S. Walley; and from Ottawa, Ont., July and August 1924, collected by Dr. J. McDunnough, Dr. F. P. Ide and Mr. G. S. Walley.

This species is named in honor of Miss Christine Hardy, to whom we are indebted for many fine specimens of this and other species of the genus *Isonychia* collected in the vicinity of Ithaca, N. Y. It occurs locally along with *albomanicata* Ndhm., with which it has probably been



confused in the past. It may be separated from that species (1) by the brighter red color of the entire body, the thorax being red instead of brownish as is *albomanicata*; (2) by the pale smoky fore tarsi; (3) by the slightly darker venation; (4) by the yellower middle and hind legs; and (5) by the darker tail bases. As compared with *christina*, true *albomanicata* appears paler and duller and of a purplish rose color; fore tarsi wholly pale or slightly tinged with rose at the joinings; middle and hind legs wholly white. The differences in the nymphs seem to support the idea that *christina* is in fact a valid species, and not a redder and darker variant of *albomanicata*. The nymph of *christina* is paler, with a continuous pale mid-dorsal line and submedian streaks on the tergites; gills pale brown instead of deep purple; usually but 7 denticles on the claw instead of 8-10; the postero-lateral spines on segments 8 and 9 relatively shorter than in *albomanicata*, that on 8 being  $\frac{2}{3}$  of 9, while in *albomanicata* the spine on 8 is but  $\frac{1}{2}$  of 9, and both spines are longer.

*Isonychia circe*, sp. nov.

A rather pale reddish species; fore tarsus smoky brown, first two joints pale at base; venation pale.

Male imago

*Size.* Body  $9\frac{1}{2}$ - $10\frac{1}{2}$  mm.; wing 9-10 mm.; tails 20 mm.; fore leg 7-8 mm.

*Head.* Yellowish. A black spot between the eye and the base of the antenna; the latter pale, tinged with red; filament dusky. Eyes purplish.

*Thorax.* Reddish, tinged with yellow. Lateral aspects of the anterior portion of the mesonotum yellowish red; a spot anterior to the mesonotal scutellum, areas on each side of this and the metanotal scutellum, and the pleura in large part, yellowish. Scutellum and sternum, and a small area in the middle of the anterior portion of the mesonotum, dark reddish brown.

*Legs.* Fore tarsus usually equal to tibia; tibia relatively short, not much longer than the femur. Fore femur dark red, paler at base; tibia dark reddish black. Tarsus smoky brown, the basal two-thirds of the first joint, the basal half of the second joint, and a narrow area at the base of the third joint, pale yellowish. Middle and hind legs clear pale yellow, the claws faintly smoky at the tip. All coxae marked with rose.

*Wings.* Hyaline. Stigmatic area somewhat opaque, whitish. Veins very pale yellowish.

*Abdomen.* Pale red, very slightly duller and paler ventrally. Basal segments slightly darker red; apical segments brighter and paler, often tinged with yellow and with powdery whitish areas; opaque. Middle segments semi-translucent. Posterior margins of all segments distinctly purplish black, these dark bands wider and deeper in color on the tergites. Pleural fold pale in the anterior half, shaded with smoky in the posterior half of each segment. A continuous smoky stripe parallels the pleural fold on the dorsum; each stigma has a small black mark. Mid-dorsal line obscurely pale, narrow at base and becoming progressively wider apically. On the middle tergites it is margined by obscure smoky submedian streaks. On the apical segments, opaque powdery white streaks may be present, two on each side of the median line.

*Tails.* White; a few of the basal joints may be faintly yellowish. Two or three joinings at the extreme base are bright red. All other joinings white.

*Genitalia.* Amber, sometimes tinged with rose. Forceps base rather deeply excavated apically. Basal joint of forceps fully three-fourths as long as the second joint. The combined terminal joints do not equal the second joint in length. Distal joint shorter than the third. Penes of the "albomanicata" type. Very broad and turning outward apically.

#### Female imago

Body or wing, 10–11 mm.

Head flesh-colored. Faint indications of a dusky pattern near the middle of the vertex, from which may be traced faint extensions forward to the bases of the ocelli, and backward to the corners of the occiput. The latter are filled by a large black spot. A narrow reddish line usually follows the inner margin of the eye, sometimes expanding anteriorly to tinge the space between the eye and the lateral ocellus. Numerous rose markings on the thorax. Venation usually as in the male; sometimes faintly yellowish brown. Abdomen brownish dorsally, dull rose ventrally. Posterior margins of the tergites rather darker and wider than in the male. Subanal plate with a moderate apical excavation, its outer angles subacute. Fore tarsus rather paler than in the male.

*Holotype*—Male imago. Collected by Prof. P. W. Fattig on Chattahoochee River, Atlanta, Georgia, August 8, 1932, No. 1252.1 in the Cornell University collection.

*Allotype*—Female imago. Same data. No. 1252.2 in the Cornell collection.

**Paratypes**—10 male imagoes, Chattahoochee River, Atlanta, Ga., on June 30, 1932, July 4–10, 1931, and August 1, 1931; 4 female imagoes, same location, July 4–10, 1931; 2 female imagoes, Alcova River, south of Monroe, Ga., August 12, 1931; 2 female imagoes, Apalachee River, north of Monroe, Ga., same date. Collector, Prof. P. W. Fattig. No. 1252.3–20 in the Cornell collection.

*Isonychia diversa* sp. nov.

*Length.* Body 9 mm.; wing 9 mm.; tails 19 mm.

A rather small brownish species with pale venation. The genitalia are unique among the members of this genus.

*Head* and thorax dark reddish brown, brightest on the notum. Pleura somewhat paler.

*Legs.* Fore femur dark red, becoming blackish at the apex. Tibia almost black. Tarsus pale reddish brown, the basal half of the first and second joints yellowish. Fore tarsus as long as the tibia. Middle and hind legs whitish, the femora slightly tinged with reddish, the claws pale smoky.

*Wings.* Hyaline. Venation wholly pale.

*Abdomen.* Smoky brown with a reddish brown tinge; paler on the middle sternites, which are somewhat translucent. Tergites 9 and 10 dark red-brown, sternites 8–10 bright reddish. Each segment has a prominent dark brown posterior margin. The pleural fold is narrowly pale on the extreme margin, above which pale line is a narrow dark reddish brown strip at the center; a small dark mark is present at the stigmatic area. Mid-dorsal line pale; very narrow on the basal segments, increasing in width posteriorly. Dark brown wedge-shaped submedian streaks bound it on each side; these are obscure basally, well marked apically. Laterad of each dark streak is another paler translucent strip, followed by a darker one. Postero-lateral angles reddish brown, antero-lateral angles paler, translucent. Sternites marked similarly to the tergites, with a rather wider pale median stripe and alternating dark and light stripes on each side.

*Tails.* White, unmarked.

*Genitalia.* Forceps base reddish; deeply excavated on its apical margin. Forceps pale. Penes differ from all other known species of this genus, and are somewhat reminiscent of the genus *Siphlophlepton*. United to form a broad base, they are suddenly incurved and then curve outward again to form more or less rounded apical lobes, which are

separated by a median V-shaped notch. Each lobe bears a slight indentation on its apical margin. The long second joint of the forceps is at least a third longer than the two terminal joints together. The basal joint is relatively long and slender.

**Holotype**—A single male imago. Taken by Dr. George Ainslee at Knoxville, Tenn., June 30, 1916. No. 1253.1 in the Cornell University collection.

*Isonychia fattigi*, sp. nov.

A dark red species with smoky fore tarsi and pale venation.

Male imago

**Size.** Body 10–11½ mm.; wing 10½–11½ mm.; tails 25–30 mm.

**Head.** Frons pale, translucent; suffused with red on the carina, frontal margin, and around the bases of the antennae. Blackish shading between the ocelli, and a black spot between the eye and the antenna. Antennal filament pale brownish. Eyes dark purplish (alcoholic specimen).

**Thorax.** Reddish black; mesonotal scutellum, metanotum, and sternum blackish. Pleura paler with deep rose markings.

**Legs.** Femur and tibia of fore leg reddish black; tarsus smoky brown, somewhat darker at the apex of each joint. Tarsus fully as long as tibia. Middle and hind legs yellowish white; coxae rose-colored; distal joint of tarsus, and tarsal joinings, reddish.

**Wings.** Hyaline. Stigmatic area more or less opaque, whitish. Longitudinal veins of the costal margin of the fore wing very pale yellowish; all other veins colorless.

**Abdomen.** Dark wine red, not paler ventrally; apical segments brighter red. Posterior margins of all segments rather widely blackish; a black line parallels the pleural fold. Basal portion of each sternite rather paler and somewhat translucent; antero-lateral angles of tergites slightly translucent. Mid-dorsal line obscurely paler; narrow dark submedian and lateral streaks may be present, usually much obscured.

**Tails.** White, tinged with reddish at base. Joinings of the first 8 or 10 basal segments red; all other joinings paler.

**Genitalia.** Forceps base reddish brown; deeply excavated on its apical margin. Forceps reddish brown, the terminal joints pale. Penes amber-colored; of the "*albomanicata*" type. The long second joint of the forceps is somewhat longer than the combined terminal joints.

## Female imago

Body 11–12 mm.; wing 13–14 mm.

Head whitish, suffused with red. Frons as in male. A geminate median rose streak on the vertex and occiput. A large red spot between the eye and the lateral ocellus. Bases of ocelli suffused with red; space between the lateral ocelli wholly or in part red. A large black spot in the corner of the occiput, and a black shading along the entire posterior margin of the head.

Pronotum creamy white, suffused with rose. Thorax with more numerous and extensive rose markings than in the male. Basal portion of each joint of the fore tarsus pale, the apical half of each dull ruddy. Venation very pale brown.

Lateral extension of the 9th segment translucent. Subanal plate rather deeply excavated apically; the outer angles subacute.

Holotype—Male imago. Collected by Prof. P. W. Fattig on Swamp Creek, Dalton, Georgia, May 25, 1931. No. 1254.1 in the Cornell University collection.

Allotype—Female imago. Same data, June 1931. Same collector. No. 1254.2 in the Cornell collection.

Paratypes—2 male imagoes, 2 female imagoes, same data as above; also 2 females, Apalachee River near Monroe, Ga., June 12, 1931; same collector. No. 1254.3–8 in the Cornell collection.

In addition to the type specimens, a female with similar markings, but rather paler, was taken at Toccoa Falls, Ga., July 5, 1931, by Girl Scouts, for Prof. Fattig.

I take pleasure in naming this beautiful species for Prof. Fattig of Emory University, who collected these and many other fine specimens from Georgia. He states that these specimens "were obtained by sweeping the leaves of the trees and bushes."

*Isonychia harperi*, sp. nov.

A rather dark red species; fore tarsus reddish brown, venation pale.

## Male imago

*Size.* Body 12 mm.; wing 12 mm.; tails 25–30 mm.; fore leg 8 mm.

*Head.* Reddish. Eyes purplish, transverse band blue.

*Thorax.* Notum and sternum reddish black. Pleura paler, rather sharply marked off from the darker notum, and with rose markings. Mesonotal scutellum and adjacent areas deep reddish black; a rose spot

anterior to it. Metanotal scutellum and the posterior portion of the mesosternum also very dark, as well as a small area at the anterior margin of the mesonotum.

*Legs.* Fore tarsus slightly longer than the tibia. Femur dark red, paler at the base; tibia deep reddish black. Tarsus reddish brown, slightly paler on the basal third of the first joint and the two distal joints. Middle and hind legs greenish white, the claws reddish.

*Wings.* Hyaline, iridescent. Venation very pale yellowish, each of the longitudinal veins outlined by two narrow dark lines. Stigmatic area opaque whitish.

*Abdomen.* Dark wine red; all segments slightly paler at the base, thus presenting a somewhat annulate appearance. Apical segments brighter red, opaque; middle segments semi-translucent. Posterior margins of all segments darker, rather wide and black on the tergites, narrower and paler on the sternites. Pleural fold marked by two dusky parallel lines, one on the extreme margin and the other dorsal to it; often a paler streak lies next to pleural fold ventrally. A short black dash marks the stigma. Paler mid-dorsal line and submedian streaks usually almost obsolescent.

*Tails.* Deep reddish brown basally for about 2 mm.; remainder of tail white. All joinings colorless.

*Genitalia.* Forceps base reddish brown, deeply excavated apically. Forceps deep smoky brown basally, the terminal joint paler. Penes reddish brown; of the "albomanicata" type.

#### Female imago

*Head* yellowish. A large spot of dark red between the eye and the lateral ocellus. Corners of occiput black, the dark shading more or less continuous across the entire posterior margin. Narrow extensions from this dark margin form blackish markings on each side of the pale median line on occiput and vertex. Venation light brown. Thorax with extensive deep rose markings. Subanal plate with only a moderate apical excavation, its outer angles subacute. Tails pale reddish at base, yellow for a short distance beyond, becoming rather flesh-colored distally.

*Holotype*—Male imago. Collected by Mr. L. Harper at Ft. Jackson, N. Y., the St. Regis River, Sept. 2-3, 1932. No. 1255.1 in the Cornell collection.

*Allotype*—Female imago. Same data. No. 1255.2 in the Cornell collection.

Paratypes—2 male imagoes, same data; 4 male and 4 female imagoes, same locality, August 24 and 30, 1932. Same collector. No. 1255.3-12 in the Cornell collection.

Other specimens in the Cornell collection which seem to be of this species are from Cascadilla Creek, Ithaca, N. Y., July 20, 1932, and from Wilseyville, N. Y., August 1932, collected by J. R. Traver; from Kellogg Creek near Painesville, Ohio, September 11, 1932, same collector; and from Hopkinton, N. Y., June 28, 1932, by Mr. L. Harper.

The species is named for Mr. Lawrence Harper, who collected these and many other fine specimens for the Cornell University collection.

One of the specimens from Kellogg Creek, Ohio, which is placed in this species tentatively, was reared from a dark reddish brown nymph in which the tibial spine of the fore leg is so strongly outcurved as to be almost sickle-shaped. Antennae dark brown; a pale mid-dorsal stripe on the basal tergites only; each tergite darker brown in the anterior half. Claws with 7-8 denticles; gills and postero-lateral spines on 8 and 9 very similar to *albomanicata*.

*Isonychia matilda*, sp. nov.

A dark red species; fore tarsus and tails dark reddish brown; venation dark brown.

Male imago

*Size.* Body 12 mm.; wing 12 mm.; tails 18-24 mm.; fore leg 9-10 mm.

*Head.* Dark reddish black. Eyes dark grey.

*Thorax.* Notum and sternum deep reddish black, pleura reddish brown. Creamy white areas suffused with deep rose anterior to the wing roots and on the pleura above each leg.

*Legs.* Fore tibia deep reddish black; femur very dark red, paler basally; tarsus entirely dark reddish brown. Tarsus slightly exceeds the tibia in length. Middle and hind legs yellowish white; femora sometimes faintly tinged with reddish and with indistinct dusky pencillings; tarsi and apical half of tibia tinged with pale reddish; claws and distal tarsal joint somewhat dusky.

*Wings.* Hyaline, iridescent. Venation dark reddish brown. Stigmatic area tinged with reddish brown, the cross veins very numerous, often forking and anastomosed. The apical third of the fore wing is sometimes very faintly tinged with brown, most noticeable on the outer margin.

*Abdomen.* Deep dark red dorsally and ventrally, the apical segments brighter red. The basal and middle segments have a narrow pale translucent area at the anterior margin; the remainder of each of these segments is often semi-translucent. Apical segments are opaque. Each segment has a narrow black posterior margin. The pleural fold is margined by a double black line; a third blackish line lies parallel to these on the dorsal side. Only faint traces of a paler mid-dorsal line and of submedian streaks are present, but narrow black lateral streaks are evident on the middle tergites. A continuous pale reddish mid-ventral streak extends the length of the venter, with the usual pale oblique submedian streaks, a tiny pale dot at the end of each; two small pale dots also near the center of each sternite.

*Tails.* Dark reddish brown, becoming pale brown toward the tips. Joinings very narrowly paler than the joints.

*Genitalia.* Dark reddish brown. Forceps base deeply excavated apically. The combined terminal joints of the forceps are approximately equal in length to the long second joint. Penes of the "albomani-cata" type.

#### Female imago

Frontal portion of head pale brown, with dark brown markings at the bases of the antennae and ocelli. Vertex and occiput greyish. Dark reddish brown between the bases of the ocelli. A narrow purplish brown line follows the inner margin of the eye; corners of the occiput purplish brown, this color extending across the posterior margin. Mesonotum yellowish brown. Abdomen slightly paler than the male, the lateral dark streaks obsolete. Subanal plate rather deeply excavated apically, its outer angles acute.

#### Nymph

Head and thorax very dark olive brown, sometimes tinged with dark red. Abdomen very dark red; reddish black apically. A pale median stripe on the frontal carina, head and thorax, sometimes interrupted by a brown area between the ocelli. Antennae deep reddish brown at the base, becoming gradually paler brown on the middle and distal joints.

Legs deep red-brown with large pale areas. Tibial spine of fore leg approximately one-half the length of the tarsus; moderately stout, slightly outcurved apically. Claws usually with but 5 denticles each. Faint traces of a narrow pale median line and of pale submedian streaks on the basal tergites. Gill lamellae deep purplish red, whitish at the



base and along the anterior margin. Postero-lateral spine on the 9th segment is but slightly longer than the spine on 8.

**Holotype**—Male imago. Collected by Dr. J. G. Needham in Wild Flower Preserve, Slaterville, N. Y., August 1932. No. 1256.1 in the Cornell University collection.

**Allotype**—Female imago. Same locality, Sept. 11, 1931; reared. Collector, J. R. Traver. No. 1256.2 in the Cornell collection.

**Paratypes**—4 male imagoes, 6 female imagoes, same locality, August and Sept. 1931, reared; collector, J. R. Traver. 2 female imagoes, same locality, August 1932; collector, J. G. Needham. 1 male and 1 female imago, Wilseyville, N. Y., August 1931, reared; collector, J. R. Traver. No. 1256.3–16 in the Cornell collection.

We have specimens of this species also from the Wild Life Preserve at McLean, N. Y., August 26, 1925.

*Isonychia pictipes*, sp. nov.

A small pale species; fore tibia bicolored, pale in middle, dark at each end; venation pale.

Male imago

*Size.* Body 8–9 mm.; wing 8–10 mm.; tails 18–22 mm.

*Head.* Pale reddish. Frontal margin narrowly black; a black spot between the eye and the antenna. Antennal filament dusky at base, pale at tip.

*Thorax.* Reddish with a yellowish tinge. Middle of mesonotum, the scutella of the meso- and metanota, and the sternum darker reddish brown. Lateral aspect of the anterior portion of the mesonotum and sides of the metanotum distinctly yellowish. Pale lavender shading anterior to the wing root, and on some of the pleural sutures.

*Legs.*—Fore femur madder red, paler at base; margined narrowly with black in the apical half. Tibia bicolored; pale yellowish in the central part, the basal third and a narrower apical band dark reddish brown. Tarsus pale smoky brown, the basal half of the 1st and 2nd joints and the basal third of the 3rd joint pale, whitish. Fore tarsus slightly exceeds the tibia in length. Middle and hind legs whitish, with a faint amber tinge; claws pale smoky.

*Wings.* Hyaline; a small portion on the stigmatic area opaque whitish. Venation wholly pale.

*Abdomen.* Pale reddish, paler ventrally. Basal segments darker,

apical segments brighter red. Posterior margins of all segments with prominent purplish black bands, wider on the tergites. A short black line marks each stigma and a rather wide dusky stripe closely parallels the pleural fold on each tergite. An indistinct paler mid-dorsal line is usually present, but more or less obscure. No dark submedian nor lateral streaks.

*Tails.* Pale yellowish white; tips entirely white. Two or three of the basal joints may be faintly pinkish. All joinings pale.

*Genitalia.* Yellow, often tinged with reddish. Forceps base deeply excavated apically, its lateral arms rather wide. The combined terminal joints do not equal the second joint in length; and, of the terminal joints, the distal is the shorter. Penes quite similar in form to *sicca* Walsh.

#### Female imago

Body or wing, 11 mm. Head flesh-colored. No red median mark on the vertex. A faint narrow reddish line follows the inner margin of each eye. A large black spot is in each corner of the occiput, and a smaller dark dot laterad of this, nearer the median line. A double black line is present on each side of the anterior margin of the pronotum; posterior margin also dusky. Veins pale yellowish. The opaque area in the stigma is more extensive than in the male. Pale mid-dorsal abdominal line obsolescent. Subanal plate and lateral extension of the 9th segment translucent; the former rather deeply excavated apically, its outer angles acute.

Holotype—Male imago. Collected by Prof. P. W. Fattig in Williamson Swamp Creek, Bartow, Georgia, May 31, 1931. No. 1257.1 in Cornell University collection.

Allotype—Female imago—Apalachee River north of Monroe, Georgia, August 12, 1931. Same collector. No. 1257.2 in the Cornell collection.

Paratypes—4 male imagoes, same data as allotype; 2 male imagoes, Alcova River south of Monroe, Georgia; same collector. No. 1257.3-8 in the Cornell collection.

#### *Isonychia sadleri*, sp. nov.

A large red species with smoky brown fore tarsi and pale venation

#### Male imago

*Size.* Body 14-16 mm.; wing 13-14 mm.; fore leg 9-10 mm.; tails 30-35 mm.

*Head.* Frons pale reddish. A black spot between the eye and the base of the antenna. Median carina and frontal margin narrowly red; base of antenna washed with red. Antennal filament whitish. Ocelli ringed at base with very dark reddish brown. Vertex dark reddish brown. Eyes purplish, transverse band pale.

*Thorax.* Very dark reddish brown; pleura paler brown, usually with extensive deep rose markings above the legs. A paler spot anterior to the mesonotal scutellum. Scutella of the meso- and metanota, the median area of the metanotum, and the mesosternum, very dark reddish black. Anterior portion of the metanotum, and areas laterad of the scutellum pale, usually tinged with deep rose. Narrow rose markings on the sides of the mesonotum.

*Legs.* Fore leg shorter than the body; tarsus fully as long as the tibia. Femur very dark reddish brown, somewhat paler basally. Tibia deep reddish black. Tarsus dark smoky brown; the base of the first joint, the sides of the fourth joint, and a narrow streak at the base of the distal joint, tend to be paler. Middle and hind legs yellowish white; claws and all tarsal joinings reddish. Coxae marked with rose. The last tarsal joint is tinged with smoky red.

*Wings.* Hyaline. Main longitudinal veins of the fore wing each outlined by two narrow parallel brownish lines. Stigmatic area opaque whitish, cross veins colorless. All other veins very pale yellowish brown.

*Abdomen.* Intense dark red; segments 6-10 largely bright red; dorsum and venter very similar. All segments with rather wide black posterior margins, wider on the tergites. On tergites 3-9, a very narrow pale streak margins this dark border posteriorly, in the median area. Pleural fold bordered with black on each tergite except for a narrow pale area at each anterior and posterior margin. Traces of a rather wide paler mid-dorsal line are most evident on the apical segments. Obscure dark submedian streaks may border this line; apically these may be replaced by bright red. The usual pale oblique submedian streaks are present on the venter.

*Tails.* White, tinged with reddish brown at the base. The first 6 or 8 joinings near the base are dark red; all others are colorless.

*Genitalia.* Forceps base reddish brown; deeply excavated on its apical margin, its lateral arms rather wider than in *albomanicata* Ndhm. Forceps dark brown, paler apically. The combined terminal joints are not quite equal in length to the long second joint. Distal joint shorter than the third joint. Penes of the "*albomanicata*" type; pale reddish brown.

## Female imago

*Size.* Body 17 mm.; wing 16 mm.

Frontal portion of head as in the male. Vertex and occiput yellowish, with a median geminate reddish streak which is widest just back of the ocelli. Space between the eye and the lateral ocellus dark red. Corners of the occiput filled by a black spot. Mesonotum greenish yellow. Thorax with numerous deep rose markings. Venation slightly darker than in the male. Pale mid-dorsal abdominal line present the length of the abdomen; on apical segments, margined by bright red submedian streaks. Abdomen brighter and paler than in the male. Lateral extension of the 9th segment translucent, tinged with red. Subanal plate rather deeply excavated apically, its outer angles subacute. Tails yellowish at base, otherwise as in the male.

*Holotype*—Male imago. Collected by Dr. W. O. Sadler at Fish Hatchery on Cascadilla Creek, Ithaca, N. Y., June 12, 1932. No. 1258.1 in Cornell University collection.

*Allotype*—Female imago—Same data. No. 1258.2 in the Cornell collection.

*Paratypes*—10 male imagoes, same data; 1 male imago, same location, June 19, 1931. All collected by Dr. Sadler. No. 1258.3–13 in the Cornell collection.

This species I name for Dr. Sadler, who collected the specimens from the hatchery ponds, where they had fallen upon the surface of the water.

A single teneral male imago, reared from a nymph taken in Ringwood Creek in Ellis Hollow, N. Y., is probably of this species. The nymph is dark reddish brown with a prominent wide pale mid-dorsal stripe the length of the abdomen. The basal joint of the antenna is pale in part; immediately beyond this, the joints are very dark brown, becoming paler distally. Tibial spine rather slender and slightly outcurved, not quite half as long as the tarsus. Gills pale yellowish brown, darker along the anterior margin; one diffuse dark spot on the outer corner of the posterior margin. Postero-lateral spine on segment 9 slightly longer than that on segment 8.

*Isonychia thalia*, sp. nov.

1932—Traver—J. Elisha Mitchell Sci. Soc. 47: 208 (as *georgiae* McD.).

The similarity of genitalia in the specimens of *Isonychia* reared from nymphs taken in Davidson River, N. C., to those of *georgiae* McD., as

figured by Dr. McDunnough, led me to place my specimens in that species. However, material recently received from Towns Creek, Cleveland Co., Ga., sent by Prof. P. W. Fattig, proves to be the true *georgiae*, which is quite distinct in size and coloration from the specimens I had erroneously placed in that species. Slight differences in the genitalia are also evident, on further study of the two species.

I propose the name *thalia* for those specimens from Davidson River which I have previously listed under *georgiae*. Descriptions are given in the article referred to above.

Holotype—Male imago. Davidson River, N. C., July 9, 1930. Reared from nymph. No. 1259.1 in the Cornell University collection.

Allotype—Female imago—Same locality, July 21, 1930. No. 1259.2 in Cornell collection.

Paratype—Female nymph—Same locality, June 27, 1930. No. 1259.3 in Cornell collection.

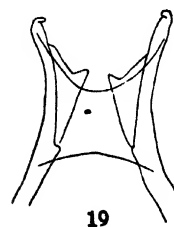
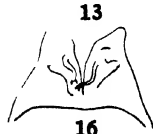
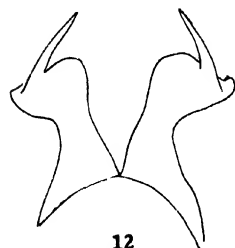
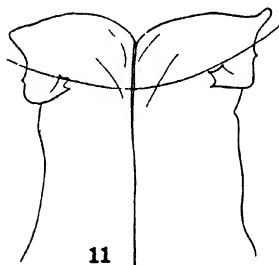
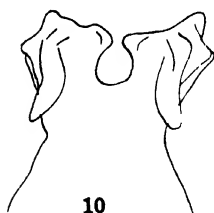
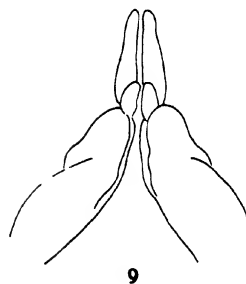
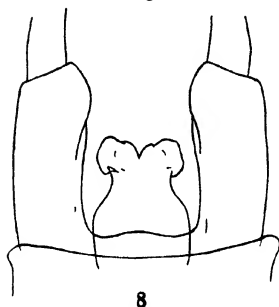
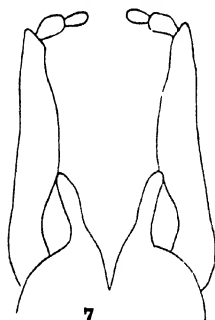
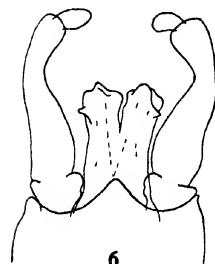
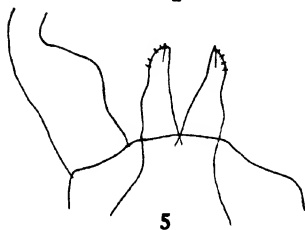
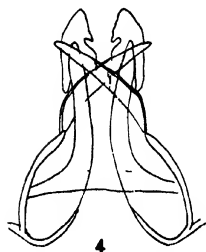
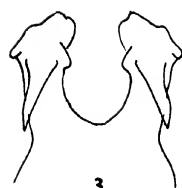
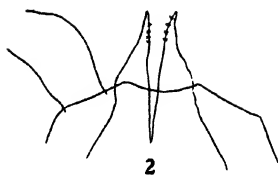
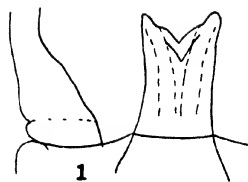
CORNELL UNIVERSITY,  
ITHACA, N. Y.

## EXPLANATION OF PLATE 16

### GENITALIA OF MALE IMAGOS

- Fig. 1. *Ephemerella euterpe* sp. nov. Penes and portion of forceps.
- Fig. 2. *Choroterpes nanita* sp. nov. Penes and portion of forceps.
- Fig. 3. *Paraleptophlebia californica* sp. nov. Penes.
- Fig. 4. *Siphonurus marshalli* sp. nov. Penes.
- Fig. 5. *Choroterpes oklahoma* sp. nov. Penes and portion of forceps.
- Fig. 6. *Ephemerella micheneri* sp. nov. Genitalia.
- Fig. 7. *Paraleptophlebia falcata* sp. nov. Forceps and forceps base.
- Fig. 8. *Isonychia diversa* sp. nov. Genitalia (upper portion of forceps omitted).
- Fig. 9. *Siphonurus spectabilis* sp. nov. Penes.
- Fig. 10. *Paraleptophlebia compar* sp. nov. Penes.
- Fig. 11. *Isonychia thalia* sp. nov. Penes.
- Fig. 12. *Thraulodes speciosus* sp. nov. Penes.
- Fig. 13. *Ephemerella maculata* sp. nov. Penes and portion of forceps.
- Fig. 14. *Habroplebiodes annulata* sp. nov. Penes and forceps base.
- Fig. 15. *Paraleptophlebia falcata* sp. nov. Penes.
- Fig. 16. *Thraulodes presidianus* sp. nov. Penes.
- Fig. 17. *Paraleptophlebia sculleni* sp. nov. Penes.
- Fig. 18. *Paraleptophlebia georgiana* sp. nov. Penes.
- Fig. 19. *Ameletus shepherdii* sp. nov. Penes.

# PLATE 16





## TECHNIQUE IN THE PREPARATION OF COLEOPTERA

By J. M. VALENTINE

### PLATE 17

The disadvantages in both the American and European methods of mounting *Coleoptera* have seemed to the author of such fundamental importance that he has undertaken to perfect a technique which would combine the desirable features of both and, at the same time, obviate most of their inadequacies.

The European entomologist habitually displays his smaller specimens by gluing them, ventral surface down, to small cards which are then pinned; the American prefers to mount his at the apex of small cardboard triangles the base of which holds the pin. In the first method, the appendages are protected and in view but only the dorsal aspect of the insect is visible, a study of the ventral necessitating the removal of the specimen from the card. This is a tedious and dangerous routine which the average collector is reluctant to undertake, a tendency which cannot fail to result in identifications based entirely on dorsal anatomy. The American system on the other hand, while providing opportunity to examine lateral and ventral characters, though only those not obscured by the legs in their flexed positions, fails to afford proper protection to the specimen. Neither technique ordinarily includes any degreasing treatment with the result that too often, during the passage of time, escaping oils render the specimen an unfit subject for study and an attractive lure to dermestids.

The author is indebted to H. S. Barber, E. A. Chapin, and L. L. Buchanan of the National Museum, and to C. Bolivar of the National Museum of Spain, for helpful suggestions.

The following procedure has been employed with success in the preparation of all carabid and cicindelid material, and will undoubtedly prove equally useful in other groups of insects.

#### I. KILLING

a. *Carbon tetrachloride*. If the fluid does not come into direct contact with the specimens, they will remain relaxed after death, especially if



the catch is large and is allowed to remain in the killing bottle at least 24 hours. A full bottle, however, should not be neglected longer as disintegration of the soft parts will soon set in with the consequent loss of setae and abdominal segments. A good vehicle for carbon tetrachloride is chopped gum rubber which imbibes the fluid readily and retains it a long time.

Advantages: 1. Kills in a relaxed condition.

2. Assists in extracting oils and fats.

3. Prepares the specimen for excessive swelling when dropped into ether, an event resulting in the extrusion of the genital apparatus.

b. *Ethyl acetate (acetic ether)*. This is a very valuable killing fluid; its use as such was first pointed out to the author by C. Bolivar whose technique is to place a few drops in a collecting tube half filled with coarsely ground cork. To insure the complete relaxing effect, it is advisable to allow the day's catch to remain in the ether-filled atmosphere at least overnight. Insects may thus be preserved, while awaiting mounting, for an indefinite period.

Advantages: 1. Ethyl acetate-killed specimens are completely relaxed and retain their flexibility when subsequently preserved in ether or alcohol. Success in relaxing such material after it has dried is far greater than when either cyanide or alcohol has been used as a killing agent.

2. Ethyl acetate is an ingredient of the relaxing fluid described below (VIII) and a solvent for cellulose cement; hence its use as a killing agent simplifies the field technique by reducing the number of necessary fluids to be carried on a trip of long duration.

## II. DEGREASING

The use of some lipid solvent in the preparation of carabid and cicindelid material is of the highest importance. Ordinary sulphuric ether (the commercial product) suffices very well. Specimens should be soaked in this until the ether ceases to grow yellow due to dissolved oils, one or two changes of the bath aiding the process when the bulk of material is great. To protect the insects from the clinging, watery exudate which falls to the bottom, a bit of loosely folded filter paper or "Kleenex" should be first placed in the bottle. This will serve to absorb such waste. Ether will preserve ethyl acetate-killed material in a perfectly relaxed condition for an indefinite period. However, a certain degree of disintegration of soft parts and surface etching will take place in very oily ether where specimens should never be left for

long; also, small specimens isolated in a volume of ether too large to be discolored by them, may become brittle if given this treatment for more than a few hours.

Advantages: 1. Swelling is accomplished by means of the ether bath, specimens killed with carbon tetrachloride becoming so turgid that usually the penis and frequently its internal sac are extruded. This is a great advantage, in so far at least as small specimens are concerned, since it eliminates the arduous and often destructive process of dissecting such material.

2. Piceous, castaneous and fulvous specimens will acquire a remarkable freshness of color, and lightly pigmented areas will appear in vivid contrast to dark as soon as the ether has evaporated. Likewise, the true texture of the chitin, a useful habitus character dependent upon clean microsculpture, is preserved as in life.

3. Never soiled with a sticky layer of grease to which dust and fine litter adhere, the ether-treated specimen can always be quickly cleaned with a camel's hair brush without endangering setae.

4. The greaseless insect can be firmly cemented to the mounting support; should it become dislodged, its lightness, compensating for brittleness of limb, will insure a good chance of its survival intact.

5. If the direct pinning method is used, a grease-free specimen will not corrode the pin.

### III. EXTRACTING GENITALIA

Specimens, the display of whose genital structures is required, should be killed with carbon tetrachloride and swelled in ether. This will result in the automatic, more or less complete extrusion of the genitalia of both sexes. Partial extrusions of the genital apparatus of males may be successfully completed by slight pressure on the abdomen; if this is not sufficient, the insect is placed ventral surface uppermost on a pad of absorbent tissue, such as "Kleenex," and held while a sharp needle is inserted in the membranous orifice of the median lobe and the latter gently pulled counter-clockwise in the direction of its curvature. This method is far more effective than simply gripping the protruding tip of the penis with forceps and pulling it posteriorly, since the genital apparatus is directed laterally by its curved sheath. If the specimen is minute, the operation should be performed in fluid (ether or alcohol) under a binocular, a special tool of fine pin-wire or drawn glass holding the insect firmly against the bottom of the dissecting dish (Fig. 1).

Soaking in ether will not effect the extrusion of genitalia from the abdomens of dried specimens.

## IV. MOUNTING

As soon as specimens are removed from the ether bath, they should be placed on a pad of absorbent paper, where their appendages are arranged, and then transferred to a smooth, clean surface (preferably glass). The legs are folded close to and on a plane with the body; the antennae are directed backward along the sides; jaws are separated by means of forceps introduced from beneath and are gently cleaned with a soft brush; the male's genitalia are left attached to the abdomen and should point to the left. A sufficient series of each species collected at one time and under the same ecological conditions are then assembled and are ready for mounting as soon as the surface ether has evaporated. Mounting should be done before the material has dried stiff, since the legs in drying tend to elevate the body slightly and this necessitates relaxing the specimens again before they can be conveniently cemented to a plane surface.

The foregoing technique is preliminary to mounting on a transparent supporting surface, though it does not preclude pinning in the usual manner. The former system, applicable to large specimens as well as small, has been developed in two ways:

a. *Cellulose acetate mounting.* Only the best quality, flat, heavy (1½ inch) acetate sheeting can be used to advantage. Each species-time-habitat series is cemented separately thereon in a compact group of one or more rows; in mounts of two rows, the front rank may be made up of females with spread jaws and the rear rank of males with extended genitalia (Fig. 2). Adequate space is left between the groups so that they may be cut apart without danger to appendages; and an ample margin of free sheeting should remain in back of each group in order that the pin, which is placed there, may not interfere with hand lens observations of the specimens nearest it. A large acetate slip supporting several good-sized beetles had best be pinned through the center.

No cement containing a solvent for cellulose acetate (ethyl and amyl acetate or acetone) should be used as it will cause the sheeting to curl. White shellac of the best quality is an adequate adhesive for mounting on acetate sheeting.

Advantages: 1. By the transparent slip method of mounting, displayed appendages are protected from breakage yet may be viewed both from above and below; the optical properties of a good grade of acetate sheeting are such that minute characters, such as in buccal anatomy, may be studied through it with ease under the binocular.

2. Pin labels are readable from above.

3. Mutilation of specimens and interference with hand lens examination by pins thrust through elytra are eliminated.

4. An assemblage of specimens illustrative of a circumscribed population of a species provides a far more valuable sample than isolated specimens and should be kept intact under the same label; the slip method of mounting makes this possible for large specimens as well as small.

5. A saving of time is effected when specimens are mounted in series by reducing the number of labels necessary and speeding up transfer from one box to another.

6. Space is conserved through the close approximation of specimens on the mounting slip.

7. Fewer pins are used.

b. *Cover-glass mounting.* This is merely a refinement of the above technique, micro cover-glass (no. 1 or 2) being used in place of acetate sheeting. Cover-glass can be easily cut with a diamond point. A small chip diamond set point outward with tar-resin cement at the end of a drawn glass tube makes a perfect instrument for the purpose. The glass may be cut to the required size after the specimen or series has been cemented to it. It is imperative to work on a perfectly smooth, level surface such as plate glass, and to use a rule which will not slip, e.g., a microscope slide faced on one side with adhesive tape.

Any cement of cellulose base, such as that put up by the du Pont Company, may be used to advantage in the affixing of specimens to the glass providing it has been sufficiently diluted with ethyl acetate to insure good capillarity. A generous application of *very thick* acetate cement or thickened white shellac of the finest quality should be used to attach a 5 mm. wide acetate strip along the entire rear margin of the mount (Fig. 2). This strip holds the pin and acts as an effective shock absorber rendering the mount practically indestructible.

Advantages: All the desirable features of the acetate sheet method plus the following:

1. Perfect and permanent optical properties.

2. A drop of ethyl acetate under a specimen will immediately free it from the glass without damage to the mount.

## V. PINNING

A glass-topped pinning block greatly facilitates this process. It can easily be constructed of plaster in a mold slightly larger ( $\frac{1}{8}$  inch on either side) than the future glass pinning surface. The latter is composed of two pieces of plate glass (3 inches square) aligned along one edge but

held slightly apart by two narrow strips cut from the ends of a microscope slide, inserted in the slot between the plates at the corners and cemented there in an upright position. The thickness of these lateral pieces should gauge the width of the slot just to accommodate the shaft of a no. 5 insect pin. Two microscope slides are then placed at right angles with the top plates, flush with and on either side of the slot and contiguous with the lateral pieces to which they are cemented. The gap between the ends of the lateral pieces and the longitudinal free margins of the slides (a distance equal to the thickness of the top plates) is filled by a strip of appropriate width cut the full length of a slide and cemented in place to form the floor of the slot. The slot depth, from the free surface of the top plates to the inner edge of this strip, now measures about seven-tenths the height of the average insect pin and gauges the correct position on the pin of the transparent mounting supports. Additional gauges for pin label heights may be had by simply inserting small, glass rectangles of the proper widths at one end of the slot. The whole structure is then placed, top downward, in the center of the mold and plaster is poured over it to a depth greater than the walls of the slot (Fig. 3).

The slotted pinning block makes it possible to pin mounting slips squarely with reference to the transverse axis, yet with the longitudinal axis at a slight angle to the horizontal. It is advisable, when pinning glass slips, to tilt the mount slightly upward in front so as to compensate for gravity and to strengthen it, when heavy, by means of a small acetate supporting strip pinned beneath the mount and inclined to meet it (Fig. 2). Pinning the glass mount after the cement which holds it to its acetate base has thoroughly hardened, will eliminate a tendency for the mount to sag on the pin.

A short millimeter scale, scratched on the glass surface of the mounting block with a diamond point, will prove an aid in the cutting of acetate strips.

## VI. MOUNTING DISSECTIONS

Preparations of mouth parts, genitalia, etc., may be attached to the pin bearing the specimens which yielded them. On one end of a conveniently long rectangle of acetate sheeting, the balsam mount is placed and covered with a tiny square of cover glass cut to fit; through the other end is thrust the pin. A preparation of this sort can be studied under the compound microscope without removal from the pin; after examination, it is swung back out of the way beneath the specimen mount.

## VII. CARE OF ACCESSORY MATERIAL

The flat tin boxes in which fifty cigarettes are sold provide admirable storage facilities for *Coleoptera*. They may be made to do double duty if both top and bottom are used. Two pieces of heavy bristol board are attached, one to each of the inner surfaces, by means of a suitable cement such as "Metallic X." To these cards, the ethyl acetate-killed specimens, with legs at their sides and antennae pointing backward, are attached in close array while still relaxed, dilute cellulose cement being employed. Each lot representing a day's catch or an ecological aggregate is circumscribed with an ink line and labeled with the date and locality, or with the date plus some symbol referring to a category in the chronologically arranged notes. The boxes are stored vertically, hinge uppermost, each bearing an adhesive tape label along its narrow, outer side. If the cementing process has been properly done, the chance of specimens breaking loose is extremely remote.

If at any time a specimen is required for mounting, it may be immediately detached from the cardboard after an application, by brush or pipette, of ethyl acetate; it should then be immersed in the relaxing bath (VIII) where the residual cement will be dissolved.

## VIII. Relaxing:

The author has found the relaxing agent developed at the U. S. National Museum by H. S. Barber and others to be extremely efficient. In this fluid, ethyl-acetate-killed specimens become plastic almost instantly and genital dissections may be made a very short time after immersion. It is invaluable for rejuvenating old, greasy specimens, and will dissolve every mounting adhesive now in common use. The formula is quoted herewith:

	<i>Parts</i>
Alcohol (95 per cent).....	265
Water.....	245
Ethyl acetate.....	95
Benzol.....	35

Should the benzol separate out, a few drops of alcohol, added slowly and shaken, will serve to bring it back into the mixture.

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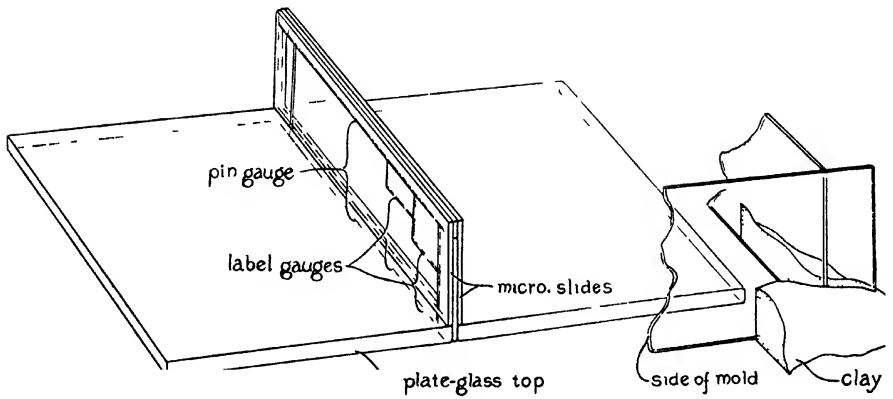
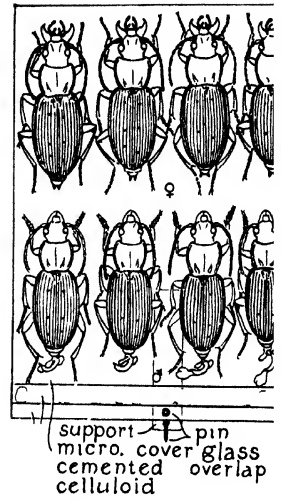
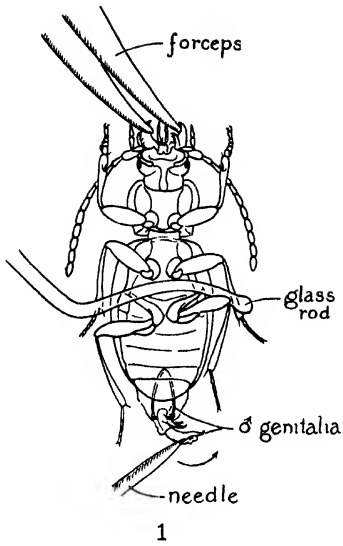
## PLATE 17

Fig. 1. Preparing a minute, male carabid for mounting.

Fig. 2. The cover glass method of mounting.

Fig. 3. A slot pinning block in process of construction.

# PLATE 17







## RHYTHM, SYNCHRONISM, AND ALTERNATION IN THE STRIDULATION OF ORTHOPTERA<sup>1</sup>

By B. B. FULTON

Love of rhythm is not solely a human trait for it is also inherent in many species of insects. Since it is unscientific to ascribe an emotional desire to a lowly insect we can say that they are endowed with an innate mechanism causing them to perform certain activities, such as stridulation, in a rhythmical manner.

The songs of katydids and crickets are produced by movement of the tegmina or first pair of wings. This movement is often a rapid vibration like the wing movement during flight, but I am referring here only to the more evident rhythm produced by interrupting or retarding such movement at regular intervals or by single stroke chirps at much slower cadence. The degree of rhythm exhibited by different species varies from those producing notes of irregular length and frequency to those in which uniform notes are repeated with a cadence that does not change perceptibly except as modified by temperature or other external factors. Of the species of Orthoptera whose songs are known, less than half are distinctly rhythmical. In North Carolina there are 11 out of 38 Tettigoniidae or katydids and 16 out of 36 Gryllidae or crickets whose songs exhibit a considerable degree of rhythm. Only a few of these species have a rhythm that can be called constant.

### SYNCHRONISM

Several species display a greater talent for rhythm by the apparently useless trait of synchronizing their notes when several individuals are singing within hearing distance of each other. It has been claimed by some that this is only an auditory illusion. That such is not the case can be easily demonstrated by comparing the group song of a synchronizing species with a chorus of mole crickets, which have a constant rhythm but do not synchronize. A more convincing test can be made by removing the auditory organs from several males of a synchronizing species and observing the effect on their song.

<sup>1</sup> Published with the approval of the Director of the North Carolina Experiment Station as Technical Paper No. 79.

In the United States there are six species of Orthoptera known to synchronize their songs. The most famous of all is the snowy tree cricket, *Oecanthus niveus* (De Geer). It is often abundant in vines and trees about dwellings where its rhythmical mellow notes have been heard and appreciated by many people who never learned the source of the music. Dolbear's (1) publication in 1897 was the first to point out that these cricket's chirp in unison although it is the feature of the song largely responsible for its distinctive quality. The species is known to occur in this state only in the mountain regions where I have heard it singing at several localities from Burnsville to Boone.

Allard (2) first published on the synchronized singing of *Cyrtixipha gundlachi columbiana* Caudell and *Neoconocephalus exiliscanorus* (Davis). The former is a small pale yellowish green cricket known from specimen records in the state only from Wake and Granville counties. It inhabits forest trees and according to my own experience never within reach of the ground, a fact which explains the scarcity of specimens. I have heard it singing frequently in and near Raleigh and for about 40 miles east and southwest. It sings with brief high pitched chirps about 3 to 4 per second depending on the temperature. It is impossible to even estimate how many of these crickets are singing in a tree for they all sing as one.

During the past two summers I have also listened to the song of *Neoconocephalus exiliscanorus*, which is in some ways the most remarkable of all the insects with synchronized music. All such species except this and one other sing for prolonged periods. With this species each individual repeats a short series of notes at irregular intervals but where several are singing together the chorus is continuous. Rehn and Hebard (3) described the song as "a vibrant rattling note rising and falling in intensity often ceasing as if from exhaustion." This variation in intensity however is not a feature of the individual song but is due to changes in the number of singers operating. The speed is between two and three notes per second.

The song differs also from all other synchronized insect songs that I have heard, in that the speed of the rhythm is perceptibly retarded or accelerated at frequent intervals. In spite of this the individual players come in accurately on the beat for from 3 to 10 notes and drop out again like pieces in a symphony orchestra. Sometimes they sing for longer periods but again one may sound a single note or sound notes on alternate beats for a few times. I have found the species near Raleigh only in moist or swampy woods among canes and shrubs.

Another insect that I can add to the list of synchronous singers is *Neoconocephalus caudellianus* (Davis). Its notes are louder, longer, and less vibrant than the last species. When close, the sound is an ear-splitting buzz. This species stridulates for long periods with unchanging rhythm. On one evening I counted 14 notes in 10 seconds. The species has not been previously reported from the state but has been taken in other states from New Jersey to Alabama. It was found near Raleigh in a marsh and in the surrounding area. At night they sit near the top of weeds or clumps of tall grass and synchronize with their neighbors within a range of at least thirty yards.

Two other species with synchronous songs have not been found in North Carolina. *Neoconocephalus nebrascensis* Bruner has a song similar to the last species but with slower rhythm and not so loud. *Amblycorypha rotundifolia brachyptera* Ball sings in series like *Neoconocephalus exiliscanorus*. The songs of both species have been described in an earlier publication by the writer (4).

#### ALTERNATION

For the past three summers I have made observations on the songs of certain species of Tettigoniidae, that exhibit another peculiar and equally useless trait. Instead of synchronizing their notes they attempt to keep up a continuous noise by sounding their notes between those of a neighboring singer. For want of a better term I am calling this "alternation."

My first experience with this type of singing was with caged single males of two species of *Orchelimum* from the southern part of the state. One species was *O. militare* Rehn and Hebard, which has long fluttering notes delivered with great irregularity and the other was *O. bradleyi* R. and H., which sings with buzzing notes at a rather regular rate, about one per second. It was evident from the start that *O. bradleyi* refused to sing while *O. militare* was singing. Sometimes *bradleyi* could work in two or three notes between the notes of the other species, but when the latter was singing more rapidly there was an alternation of single notes. *Orchelimum militare* would start a note while *bradleyi* was singing but the latter was always a perfect gentleman and would wait until the other had ceased.

Last summer I brought in from Lakeview several males of both species and kept them for observation. When two males of *O. bradleyi* were placed in a separate room they sang with alternating notes most of the time. When two notes happened to sound together, one of the singers

would pause for a beat and correct the mistake. With more than two singing together, more notes were sounded simultaneously and their coöperative singing was less evident. Alternation is apparently a two-handed game played by neighboring males.

With *O. militare*, two specimens singing together seemed to alternate their notes most of the time, but each would start a new note before the other had finished, keeping up a continuous sound for long intervals by overlapping the notes. It was impossible to tell whether this was accidental or not, for the song does not maintain a very uniform rhythm. One specimen had a tendency to prolong its notes sometimes for 15 to 20 seconds and evidently made no attempt to coöperate with the others. Usually the notes are from 1 to 4 seconds in length with a fairly uniform delivery at any one time but subject to change even under uniform external conditions and apparently according to the mood of the singer.

When listening to the raucous call of the true katydid, *Pterophylla camellifolia* (Fabr.), it seemed to me that the notes sounded simultaneously less often than would be expected under the law of chance. With so many katydids about, it was impossible to be sure of this so I collected two specimens and caged them separately a few paces apart in a place where there were no other katydids. When so isolated it was evident that the song of either one influenced the song of the other. There was a deliberate alternation of notes but it was not as simple as I had expected. At irregular intervals one of the katydids would sing out of turn and both would sound the note in unison or the other katydid would remain silent until the next beat and they would continue to alternate as before. Sometimes this shift would take place several times without any notes being sounded in unison. Again there would be from 1 to 5 simultaneous notes before one singer would pause and bring about alternate singing again. The notes were either clearly separated or exactly in unison as well as I could detect by ear. It was not a case of interference from two rhythmical sounds of slightly different frequency.

By counting the notes of one individual when sounded alone and when in unison with the other, several records were taken of which the following is a sample.

Alone	5	10	3	4	3	3	5	Total	33
In unison	1	1	2	1	3	2	1	Total	11

Other series counted gave the following totals.

Alone	78	322	138
In unison	36	47	33

The largest number of consecutive notes sounded in unison was 5. The largest number of consecutive notes sounded by one individual alone, while alternating, was 38.

At a temperature of 68°F. the katydid duet kept up a fairly regular rate close to 14 notes in 20 seconds, or 7 notes by each katydid. When either one was silenced by shaking the cage the other would continue at a rate of only 10 notes in 20 seconds, but three notes more for the period than it would have sung if accompanied by the other katydid. At 80°F. the rate for the duet was 22 to 24 notes in 20 seconds and the individual rate 14 to 16 notes per 20 seconds. As nearly as I could estimate the rest period between notes was about the length of the note itself when two were singing and about twice as long when one was singing. The length of the note seemed to be the same in either case.

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# ANATOMY OF THE TRANSITION REGION OF *HELIANTHUS ANNUUS*

By ALBERT F. THIEL

PLATES 18-22

## INTRODUCTION

. In preparing slides of the root and hypocotyl of the sunflower, *Helianthus annuus* L., for the general Botany laboratory, various features of its anatomy were observed which had not previously been reported. Chauveaud (1) was the first to describe briefly the transition region in the sunflower in his extensive studies on the conducting apparatus of plants. He described the stele at the base of the hypocotyl as being tetrarch with four phloem groups alternating with four xylem groups. Miss Siler (8) reported the root of the sunflower to be tetrarch with parenchymatous cells in the center of the root axis. She made a detailed study of the seedling anatomy and represented the transition with detailed drawings and with a series of diagrams. Van Tieghem (11) studied root-stem transition in a large number of seedlings of different plants and represented his findings in three diagrammatic schemes which are reproduced in Eames and McDaniels' (2) "An Introduction to Plant Anatomy." A fourth type of transition described by Miss Sargent (7) is also included in this text.

Considerable interest has developed in seedling anatomy in recent years because of its aid in studying plant affinities. The internal structure of the root and the method of root-stem transition of the vascular bundles has been found to be constant in a large number of closely related species. In some cases other workers have minimized the importance of such studies in phylogenetic interpretations. Since the anatomy of the root and the method of root-stem transition observed in a preliminary study of the sunflower did not agree with the findings of earlier investigators, further studies were considered advisable. It is the purpose of this paper to present root-stem transition in the seedling of *Helianthus annuus*.

## METHODS AND PROCEDURE

The seeds were planted in sterilized sphagnum moss placed in a moist chamber in the laboratory. By following this method it was possible to obtain a maximum number of straight hypocotyls and roots. The material was killed in a formalin acetic alcohol solution made up of the following proportions: 50 per cent alcohol, 100 parts, commercial formalin, 6 parts, and glacial acetic acid, 3 parts. The customary laboratory method of dehydrating, infiltrating, and imbedding in paraffin were followed. Five different sets of serial transverse sections were made of the seedlings varying in age from one day to seven days from date of planting. Longitudinal sections were also made through critical regions. The sections were stained with safranin and light green.

By root-stem transition is meant the change involved from the centripetal development of the primary xylem of the root to its centrifugal development in the hypocotyl, cotyledon, or stem. In describing this change the vascular structure of the root will be presented, followed by that of the hypocotyl and cotyledons.

## GROSS MORPHOLOGY

The fruit of the sunflower is an aehene varying in form from oblong to obovate and is somewhat four-angled. The embryo is straight and can be easily separated from the seed coat and ovary wall. The seeds germinate as soon as proper conditions are provided. The 7-day-old seedlings attained a total length of 150 mm. The cotyledons, hypocotyl, and root measured 15 mm., 60 mm., and 75 mm., respectively. At this age the primary permanent tissues were fully matured. Lateral roots were numerous and developed in two rows about 20 mm. from the growing point, while at successively higher levels they appeared in three and then finally in four rows.

## THE PRIMARY ROOT

The stele of the root of the primary plant body of the sunflower is diarch near the growing point and becomes triarch and tetrarch at successively higher levels. The metaxylem forms a continuous plate without any parenchymatous cells in the center of the root axis (figs. 1-2). This does not agree with the findings of Siler (8), who states: "The root is tetrarch and large cells in the center are not lignified and appear like pith cells." Siler's observations were probably made on seedlings in which the primary permanent tissues had not fully matured. That the



root is typically diarch at its lowest extremity can also be seen macroscopically by the position of the laterals as pointed out above.

As the change from the diarch to the triarch condition of the root is brought about, one observes a division of one of the primary phloem groups. At higher levels these phloem groups separate and a third xylem strand is differentiated, thus establishing the triarch condition (fig. 3). The change from the triarch to the tetrarch condition is brought about just as in the previous case. The second primary phloem group divides into two parts and each differentiates laterally, making room for the fourth primary xylem strand, which is then differentiated in this position (figs. 4-5).

In the transition zone between root and hypocotyl the tetrarch root begins to change and the central cells of the root axis no longer differentiate into lignified vessels but remain parenchymatous (fig. 6). The two xylem strands which originally formed the diarch xylem plate (px 1 and px 2) bifurcate, forming a ring of metaxylem with the single arms of the other two xylem strands (px 3 and px 4).

#### TRANSITION IN THE HYPOCOTYL

Near the base of the hypocotyl the stele enlarges very rapidly. The metaxylem ring becomes dissected, eventually forming six separate bundles (fig. 7). Four of these bundles constitute the two double bundles which lie in the cotyledonary plane and become the midribs of the cotyledons. The other two bundles lie in the intercotyledonary plane and become the lateral strands of the cotyledonary petioles. The two cotyledonary strands can readily be distinguished from the intercotyledonary by the bifurcated metaxylem of the former and the single xylem strands of the latter.

At the base of the hypocotyl there is an asymmetrical origin of the intercotyledonary phloem groups (fig. 7). This fact was first pointed out by Siler. The intercotyledonary phloem originates by a division and lateral differentiation of the two phloem groups from one of the double bundles ( $a''$  from  $a'$  and  $b''$  from  $b$ ). This one-sided division of the phloem makes this method of transition unique and different from those illustrated in Eames and McDaniels' text.

At succeeding levels higher in the axis, the metaxylem of the cotyledonary bundles (fig. 8, 1 and 3) differentiates from tangentially exarch to tangentially endarch strands. The metaxylem arms of the intercotyledonary strands (2 and 4) become detached from the metaxylem of the double bundles. There is no bifurcation of the metaxylem of

these two bundles, but instead one metaxylem arm differentiates to the right and the other to the left of their protoxylem points. At the same time the phloem groups have differentiated laterally and now lie on the same radii as the xylem. In these two intercotyledonary bundles, the primary xylem soon differentiates centrifugally and the endarch condition is established low in the hypocotyl.

As the cotyledonary node is approached, all of the bundles gradually differentiate and diverge outwardly, finally leaving the stele (fig. 9). The two cotyledonary bundles (1 and 3) differentiate tangentially endarch and the intercotyledonary bundles (2 and 4) have been endarch in development throughout most of the hypocotyl.

#### THE COTYLEDONS

The cotyledons of a 7-day-old seedling are very large, measuring approximately 15 mm. long and 8 mm. broad. The bases of the petioles form a tube around the emerging epicotyl (fig. 10). All of the bundles of the root and hypocotyl diverge into the cotyledons forming a vascular system independent of any subsequent epicotyl development. At the base of the cotyledonary tube there are the same number of bundles found in the hypocotyl, namely, the two intercotyledonary endarch bundles (fig. 10, 2 and 4), and the two tangentially endarch cotyledonary double bundles (fig. 10, 1 and 3). The intercotyledonary bundles split and become the two lateral bundles of each cotyledon (fig. 10, c and c', and fig. 11). The two lateral bundles each split again forming several lateral bundles (fig. 11). The two halves of the double bundle of a single cotyledon converge forming a large broad midrib bundle in the lamina, where all of the bundles are collateral and the primary xylem develops abaxially.

#### DISCUSSION

Many of the anatomical studies of seedlings in recent years were made to either prove or disprove some phylogenetic theory. It seems that much more careful anatomical work on seedlings is desirable, irrespective of its phylogenetic value.

Siler (8) recently reported on root-stem transition in *Helianthus annuus* and *Arctium minus*. She found the stele of the root in the sunflower to be tetrarch with no lignification of the cells in the center of the root axis. In all of the cross sections of the root examined by the writer the stele formed a diarch xylem plate nearest the growing point and changed from the diarch condition to triarch and finally tetrarch at successively higher levels in the root.

Lee (4) studied root-stem transition in a large number of families of the *Sympetales* including the *Solanaceae*. He states that plants with small seedlings have a diarch root. The writer (9, 10) previously investigated root-stem transition in seven species of the *Solanaceae* and the results confirm Lee's observations. Lee states further that plants with large seedlings have a tetrarch root. There of course must be many exceptions. The sunflower has large seedlings and the stele of the root is diarch, triarch, and tetrarch.

Sargent (6) believes that the tetrarch condition is the most primitive, while Lee (5) holds that tetrarchy and diarchy have probably been interchanged several times during the evolution of Angiosperms.

There are over 200,000 species of Angiosperms alone. The structure of the seedling has been studied in about 550 species. It would seem that, before we can draw any valuable phylogenetic conclusions from a study of seedling anatomy, we must know the structure of several thousand more seedlings.

#### SUMMARY

1. The stele of the root of the sunflower forms a diarch xylem plate near the growing point and becomes triarch and tetrarch at successively higher levels.

2. In the transition zone between root and hypocotyl two xylem strands, which originally formed the diarch xylem plate, bifurcate forming a ring of metaxylem with the single arms of the other two xylem strands.

3. Near the base of the hypocotyl, the metaxylem ring becomes dissected forming six separate bundles.

4. At succeeding levels higher in the hypocotyl, the metaxylem of the cotyledonary strands differentiates from tangentially exarch to tangentially endarch strands. This reorientation continues through the hypocotyl and up to the lamina of the cotyledon, where the direction of development of the primary xylem is just the reverse to that in the root. The intercotyledonary strands do not bifurcate but, instead, the single metaxylem arms differentiate, one to the right and the other to the left of their protoxylem points. In these two bundles the endarch condition is established low in the hypocotyl.

5. There is an asymmetrical origin of the intercotyledonary phloem groups which makes this method of transition unique and distinctive from those previously reported.

6. All of the bundles of the root and hypocotyl diverge into the coty-

ledons, forming a vascular system of the primary plant body independent of any subsequent epicotyl development.

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#### EXPLANATION OF PLATES 18-22

Abbreviations for all figures: cor, cortex; der, dermatogen; end, endodermis; ph, primary phloem; px, protoxylem; mx, metaxylem; per, pericycle; cot. b, cotyledonary bundle; intc. b, intercotyledonary bundle.

Fig. 1. Microphotograph of transverse section of root of sunflower through meristematic region showing diarch nature of stele.

Fig. 2. Transverse section of sunflower root at higher level through region of maturation.

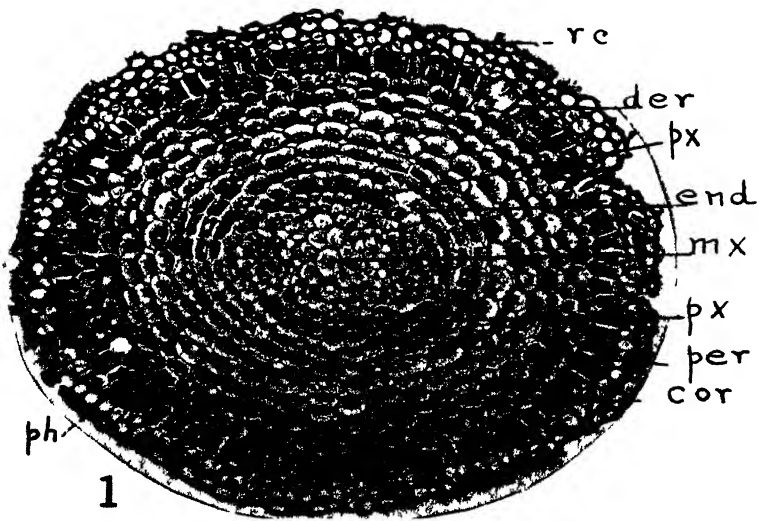
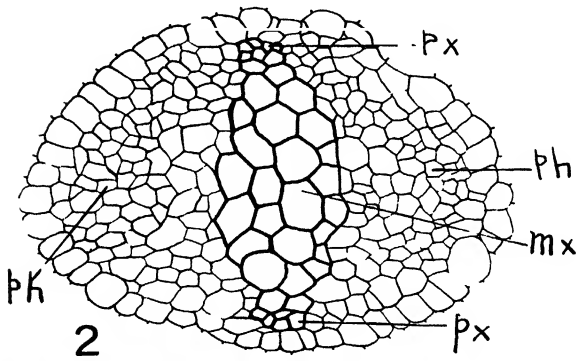
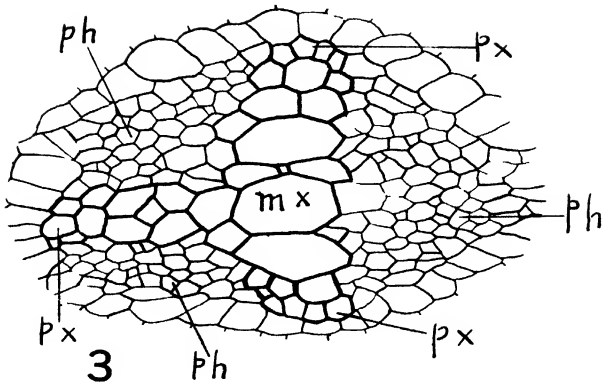
Fig. 3. Same at higher level showing the triarch xylem.

Fig. 4. Same at higher level showing origin of fourth xylem strand and separation of a primary phloem group forming the fourth group at a'. Other phloem groups at a, b, and b'.

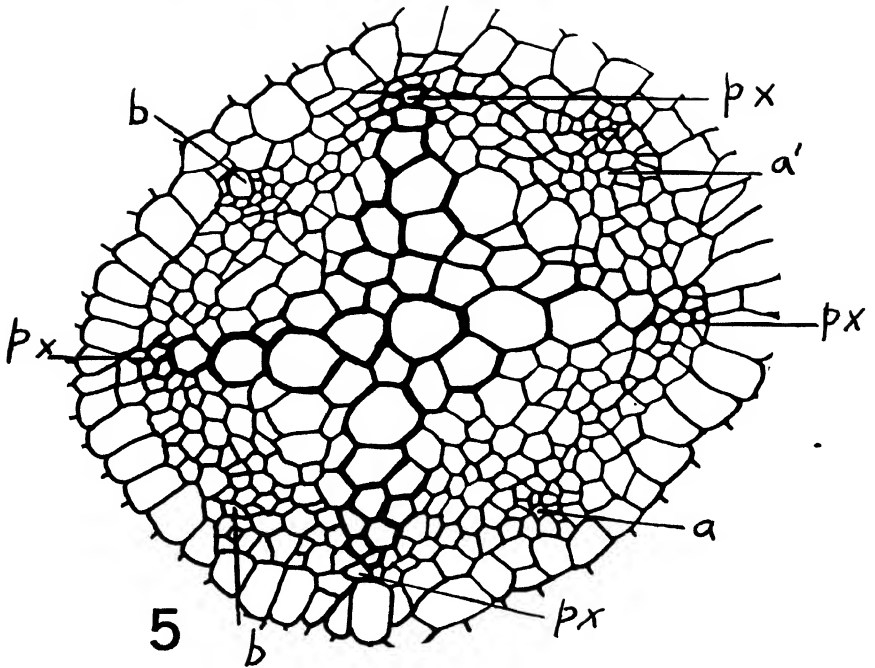
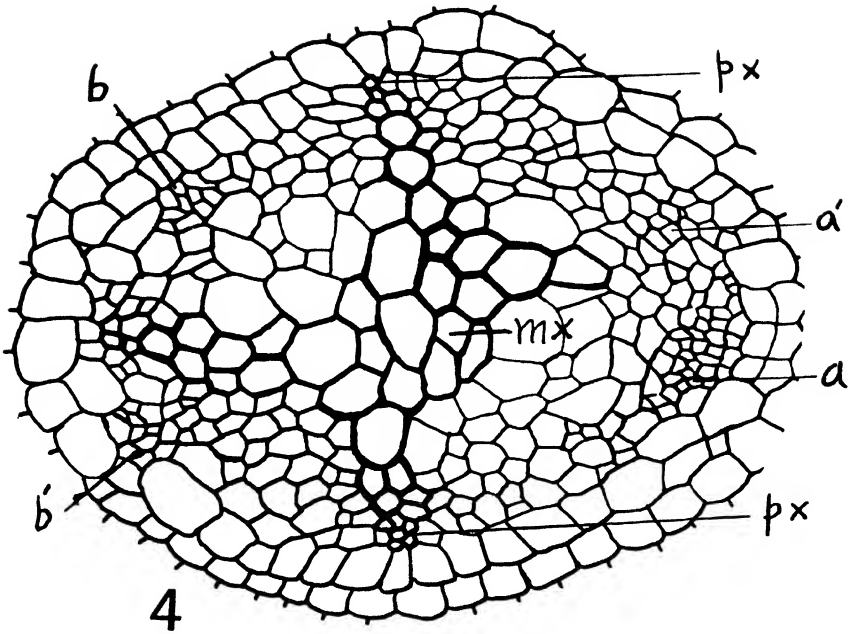
Fig. 5. Same near the upper part of root showing the tetrarch stele with the four protoxylem points (px) alternating with the four phloem groups (a, a', b, and b').

- Fig. 6. Same in the transition zone between root and hypocotyl showing bifurcation of metaxylem in the cotyledonary strands (px 1 and px 2).
- Fig. 7. Same at a higher level through transition zone between root and hypocotyl, showing bifurcated metaxylem of the cotyledonary bundles (1 and 1') and single arms of the intercotyledonary bundles (px 3, and px 4).
- Fig. 8. Microphotograph of section low in the hypocotyl showing the two double bundles which lie in the cotyledonary plane (1 and 3), and the two intercotyledonary bundles (2 and 4).
- Fig. 9. Microphotograph of transverse section of hypocotyl through the cotyledonary node showing the outward divergence of the bundles.
- Fig. 10. Microphotograph of transverse section through region forming the cotyledonary petiolar tube, showing the two cotyledonary bundles (1 and 3) forming the midrib of the petiole, and the intercotyledonary bundles (2 and 4).
- Fig. 11. Microphotograph of transverse section through petioles of cotyledons showing the lateral bundles and the midrib bundles (1 and 3). The protoxylem is nearest the upper surface of the petiole and the metaxylem differentiates abaxially.

PLATE 18











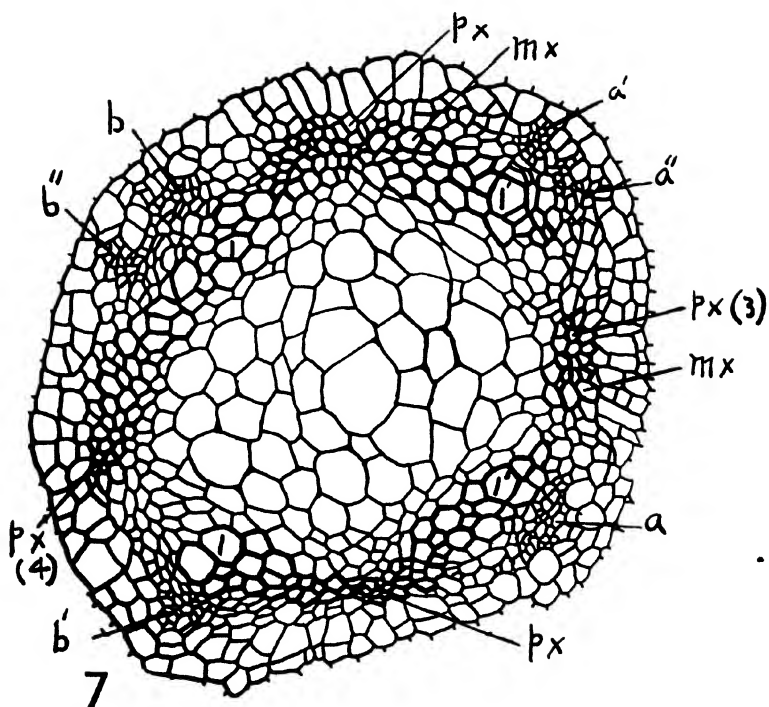
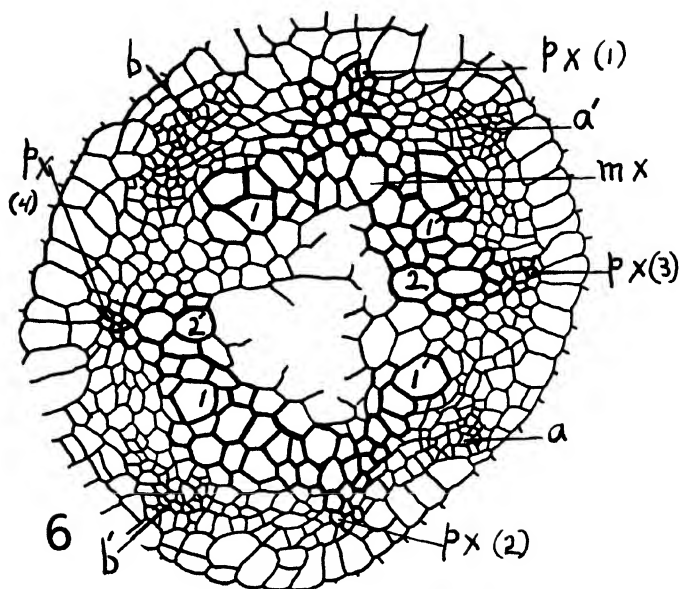
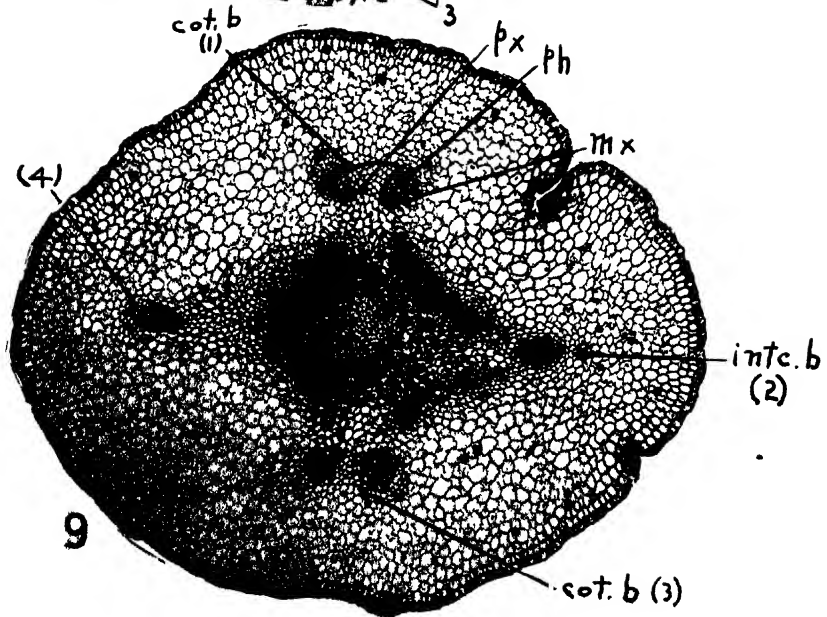
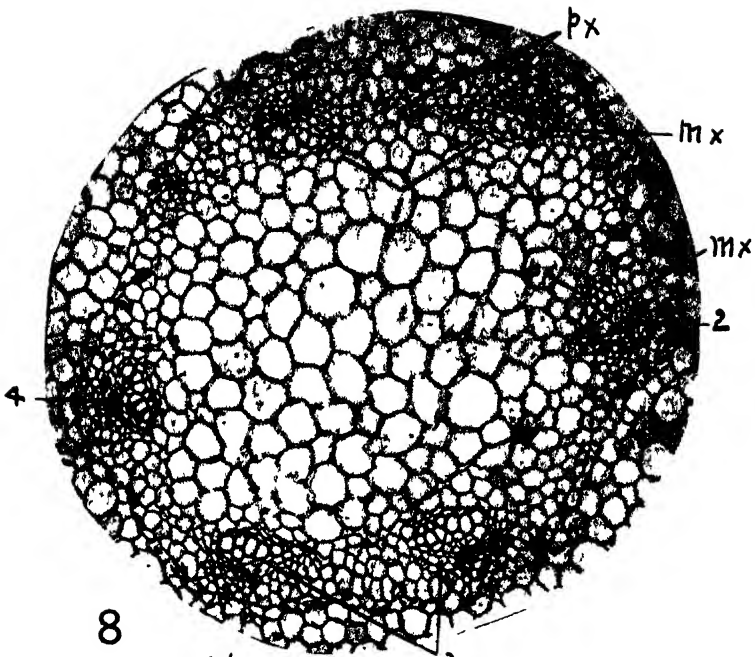
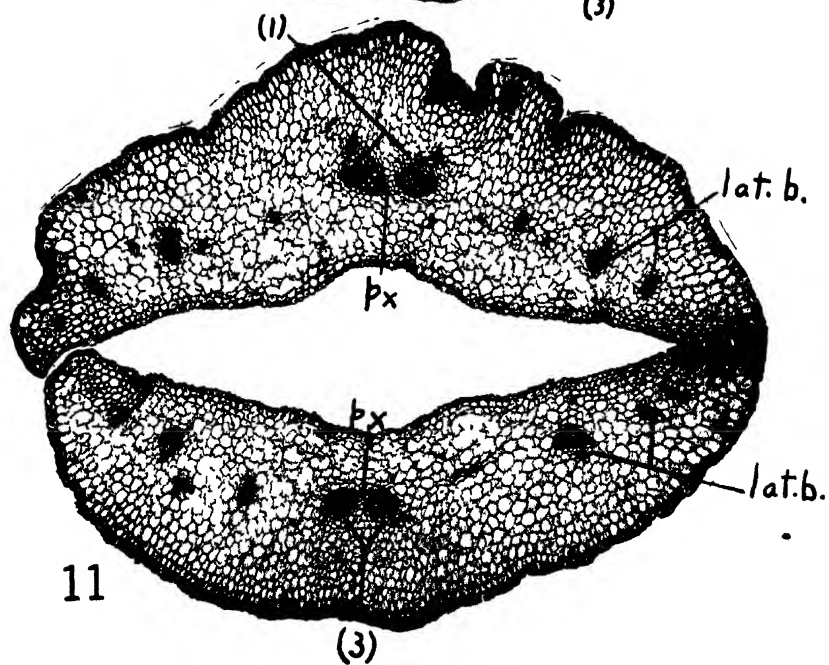
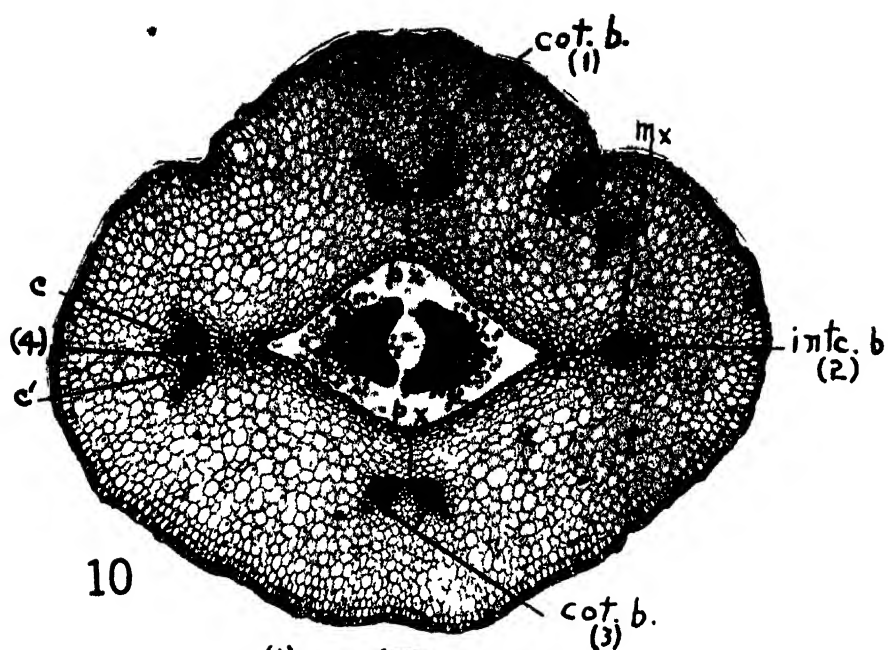




PLATE 21









# THE DEVELOPMENT OF THE FRUITING BODY OF ARACHNION ALBUM

By CAROLINE A. LANDER

## PLATES 23-26

The similarity of *Arachnion album* (Schw.) in general appearance and in younger stages of development to the species of *Lycoperdon* seemed of interest and instigated this investigation.

The form is not commonly known. The gleba, according to Coker and Couch (2), is composed of a large number of minute chambers lined by a hymenial layer apparently made up of basidia alone. Between the chambers is an interwoven tissue of delicate hyphae. At maturity the peridioles are freed as granules by the breaking down of the loose tissue. The peridium falls to pieces slowly with no definite pore. No capillitium, or columella, or sterile base is present.

## MATERIAL

The material of *Arachnion album* (Schw.) was collected during August at Chapel Hill, North Carolina. For a limited time it was abundant in open places, meadows, edges of flower beds, and paths. The fruiting bodies were killed in formalin-acetic-alcohol, Flemming's medium, or chromo-acetic solutions. Heidenhain's iron-alum haematoxylin with erythrosin or fast-green as a counter-stain gave the best results.

## OBSERVATIONS

The younger stages are very similar to those of *Lycoperdon gemmatum* (Lander, 6). The fruiting body arises either terminally or laterally on the rhizomorph as a nodular swelling formed by the increase and growth of the "building hyphae." This primordium of the carpophore is a homogeneous, spherical body composed of closely interwoven, fine hyphae. The hyphae branch frequently, are binucleate, have abundant cross walls with hemispherical pads, and contain fairly dense protoplasm.

With development this tight, compact structure of intertangled and intricately interwoven hyphae expands and becomes loose in arrangement (fig. 14). Growth is general and uniform throughout the whole structure with the peripheral development marked.



The first differentiation is one of arrangement only and takes place at the periphery. Here the hyphae are in a radial direction. Division of the cells is more rapid near the tip, resulting in short cells. Such development originates at the top of the fruiting body primordium; gradually spreading around the central region. The structure is still composed of one type of hyphae and in its center shows the same arrangement as in earlier forms with the exception that the hyphae are more loosely interwoven.

As growth and expansion continue lighter areas become noticeable in the central region (fig. 15). The first ones to appear are in the upper part, while others are soon formed at the sides and lower parts. No doubt the clear portions are due to unequal growth. Thus a stretching, pulling, and a tearing of the hyphae result. There seems to be no uniformity as to size or shape of the spaces. Study of the older stages shows this to be the first step in the differentiation of the cavities.

Small groups of differentiated hyphal tips arise close to the cavity primordium and at scattered points in the immediate region. Such hyphae are clearly distinguishable in an early stage because of the greater affinity for the stain (figs. 1, 16). The hyphae are arranged in intimate groups, intertangled, and twisted into knot-like structures; the tips radiate in all directions. In contrast to the fundamental tissue the cells are much shorter and broader, and branch abundantly in a dichotomous manner. The protoplasm is very dense and cross walls thin. A cluster of several rows of cells is formed by each hypha, the tip cell of which becomes the basidium. Figure 1 illustrates a stage in such formation.

These hyphae, the basidial primordia, radiate from their tangled position toward the opening and become arranged parallel to each other in a palisade-like layer. From the palisade layer the tips project irregularly into the cavity. The cavities rarely have a regular appearance at this stage because of the unequal growth and division of the hyphae (fig. 20). The cavities are not completely lined with the palisade tissue at any one time; instead there are scattered groups around the edge and later basidia are added to complete the hymenial layer.

The expanse of the fundamental tissue enlarges and rounds the opening; while stretching, tearing, and plasmolysis thus produced clears the cavity of all such tissue. Subsequent growth causes the evening up of the basidial tips until the contour of the cavity is regular. With the addition of new basidia and the completion of the formation of the basidial primordia a definite hymenial layer completely surrounds the

rounded cavities (figs. 17, 18). The young carpophore is filled with numerous small rounded cavities in close proximity.

The fundamental tissue between the cavities is relatively sparse and is composed of delicate hyphae varying in diameter and occasionally branching. The cross walls are thick with prominent hemispherical pads on either side. The hyphae are loosely interwoven and tend to circle or to outline the cavities.

Before the cavities are noticeable the peridium is differentiated. It is first distinguishable as a zone of profusely branched hyphae which tend to be more radial. As the cavity primordia first appear a second layer develops just beneath the first (fig. 16). This zone retains the stain more easily than the outer. It is composed of hyphae, apparently of the same type as the first, which may vary slightly in size and shape but which are interwoven more compactly and do not show the radial tendency.

With further differentiation the hyphae of the inner zone become irregular in size and shape and likewise irregular in arrangement. In some portions they fuse together and undergo other changes resulting in the formation of a pseudoparenchymatous layer. Increase in growth from the interior increases this zone. The hyphae of the outer layer expand and spread apart farther and farther, sloughing off very early (fig. 17).

The outer zone continues to slough off and the inner to increase in width so that the single peridium of the mature fruiting body is composed almost entirely of pseudoparenchymatous tissue.

The basidia completely surrounding the cavity are crowded together. They are narrowly clavate when young and broaden at the tip as they mature. Each basidium produces four sterigmata at its tip (figs. 10, 11). The sterigmata are extremely long, narrow, and thin-walled; some extending to the center of the cavity (fig. 13). They vary greatly in length in the same cavity or in different cavities. In general it would seem that the earliest formed are longer and the last quite short. The sterigmata of the same basidium will vary in length. In some cases apparently the sterigmata attain their full length before the initiation of the spore; while others grow considerably after the spore is formed, even after it has attained full size. At a definite stage the cavity is filled by a tangled mass of the long sterigmata with or without spores.

Few cases of all four spores of the basidium maturing were found though on the majority of the sterigmata spores, at least in the initial stage, were seen. The spores attain their full size before the sterigmata

break. Frequently, however, the wall of the spore is still thin and the nucleus has not divided. The mass of mature spores and broken pieces of sterigmata completely fill the cavity (figs. 13, 21).

Throughout the carpophore from its earliest stages the cells are binucleate. The two nuclei in the basidium fuse. The fusion nucleus in the apical portion of the basidium enlarges (fig. 3). The spindle of the first division is transverse to the longitudinal axis of the basidium (fig. 4). The poles taper toward the walls of the basidium and there is present a dark stained body at each pole suggestive of a centrosome. The chromatic mass divides and the halves separate and move toward the poles (fig. 4). Two daughter nuclei are organized (fig. 5). The rarity of the two-nucleate as compared with the four-nucleate and the one-nucleate stages suggests that interkinesis is of short duration.

The second division, occurring simultaneously in both daughter nuclei, takes place rapidly. The spindles of this like that of the first division lie in the apical portion of the basidium, transverse to its longitudinal axis; they make a right or oblique angle with each other (figs. 6, 7, 8). The spindles are in such close proximity that it is often difficult to distinguish one from the other. This division, so far as observed, is similar to the first, and results in the organization of four nuclei (fig. 9).

The four nuclei move to the central or basal portion of the basidium where they remain for some time. As soon as the sterigmata begin to protrude a large vacuole is formed below the nuclei; the increase in size of this vacuole seems to push the nuclei to the apical region of the basidium. When the nuclei come to lie close to the apical wall, they become fusiform. Their membranes become indistinguishable, and oftentimes it is difficult to distinguish the nuclei from one another. A nucleolus is conspicuous at this time in each nucleus; it is surrounded by a homogeneous group of dark granules.

Each nucleus moves toward the corresponding sterigma, becomes greatly elongated, and passes through the sterigma into the enlarged distal end (fig. 10). In moving through the sterigma the nucleus is stretched to a threadlike structure; as soon as it reaches the distal portion it begins to thicken. Sometimes in passing through the extremely long sterigma the nuclear material may be in a continuous fine thread, while at other times it is broken. A typical nucleus is evident soon after the complete passage of the nuclear material into the distal end. As the spore matures, either before or after breaking from the sterigma, the nucleus divides (fig. 11).

At the time of the initiation of the sterigmata the first signs of the

breaking of the fundamental tissue are noticeable. There is a definite cleavage or splitting, forming cracks or fissures between the cavities (figs. 17, 18). This tearing progresses, outlining and cutting out the cavities with their surrounding tissues from each other. The torn hyphae plasmolyze, collapse, and finally disintegrate. Surrounding the hymenial layer four or five cells in thickness, the remaining living fundamental tissue encircles the cavity in a compact zone.

When the spores have matured the disintegration has progressed to within two or three cells of the basidia. The basidia broaden and become flattened against each other; some walls fuse so that a definite layer is formed. Further changes occur until the basidial region becomes pseudoparenchymatous. A cross section of a portion of the hymenial layer illustrates this fact (fig. 12). The last cells to plasmolyze and die, collapse against the basidial layer; the walls harden and they tend to remain there for some time, strengthening the peridiole protective layer.

The mature carpophore is filled with peridioles crowded with spores, which are surrounded by protective layers of basidial origin, and separated one from the other by space (fig. 21). As the peridium crumbles away the "peridioles" are freed.

The origin of the fruiting body of *Arachnion album* and its early stages of development correspond very closely to those of certain species of *Lycoperdon* (Cunningham, 3; Lander, 6; Rehsteiner, 9; and Swartz, 10). The origin of the cavities through mechanical splitting of the hyphae; the irregular differentiation of groups of basidia primordia; and early development of the palisade tissue around the cavities are likewise similar.

However, *Arachnion* lacks the progressive splitting, enlargement, and fusions of the cavities. In this form, instead of large irregular labyrinthine cavities, numerous small rounded cavities are present.

Although the formation of the palisade tissue around the cavities is more uniform in development in *Arachnion* than in species of *Lycoperdon*, the formation of the basidia is essentially the same (Lander, 6).

The outstanding difference in the younger stages is the breaking of the fundamental tissue between the cavities in *Arachnion*. Later the formation of a pseudoparenchymatous layer by the basidia around the cavity which is filled with spores results in the formation of the peridioles. At maturity the fruiting body composed of granular peridioles, with no columella or tissue between them, and a single-layered peridium lacking the pore is easily distinguishable from *Lycoperdon*.

## SUMMARY

The fruiting body originates as in species of *Lycoperdon* as a nodular swelling on the rhizomorph laterally or terminally, and formed by the "building hyphae."

The earliest development consists only of general growth, expanse and loosening of the hyphal arrangement.

The peridium is the first to be differentiated, the hyphae of which exhibit a more radial direction.

The peridium in young stages is composed of two zones: an outer tissue of loosely interwoven hyphae with radial tendency; and an inner of intricately, closely intertangled hyphae with greater affinity for the stain.

The inner zone becomes pseudoparenchymatous and the outer sloughs off as the fruiting body matures. The single peridium at maturity is without a pore and consists chiefly of pseudoparenchymatous tissue.

Corresponding to the early stages in gleba differentiation in *Lycoperdon*, the cavities arise by an irregular mechanical splitting of the tissue; basidial primordia develop in close knot-like groups irregularly arranged in close proximity to the cavities; and gradually the palisade tissue surrounding the cavities is formed.

The progressive splitting, enlargement, fusion, and formation of irregular labyrinthine cavities in species of *Lycoperdon* is lacking in *Arachnion*. The mature gleba is composed of numerous rounded, regular cavities crowded close together.

At the time the basidia are formed the fundamental tissue splits between the cavities and progressively plasmolysis and disintegration of the tissue follow.

After the sterigmata and spores have been formed the basidia form a compact pseudoparenchymatous layer around the cavity.

The sterigmata are exceedingly long, four are produced on each basidium, and each produces one spore; though many do not mature.

Throughout the fruiting body the cells are binucleate, abundantly septate, and contain prominent hemispherical pads.

The fusion of the two nuclei in the basidium primordium is followed by an enlargement of the basidium and of the fusion nucleus. The spindle lies in the apical portion of the basidium; transverse to the longitudinal axis of the basidium. Dark stained granules are present at the poles suggestive of centrosomes. The chromatin mass becomes stretched out along the spindle, divides, and reaches the poles.

The binucleate stage is of short duration. The spindles of the second

division are likewise transverse and are at right angles or oblique to each other.

The four nuclei remain for a short time in the lower part of the basidium; later are pushed against the apical wall by a large vacuole. The nuclei become elongated; stain only as dark irregular masses; and move toward the sterigma.

The nuclear material streams in a threadlike manner through the sterigma into the distal end. The nucleus resumes its characteristic form in the spore and later divides.

This work was carried on while the writer was the holder of the Sarah Berliner Research and Lecture Fellowship given by the American Association of University Women.

The writer wishes to express her appreciation for the use of the botanical laboratory at the University of North Carolina, and to Dr. J. N. Couch for help in the collection and identification of the material; and to Dr. E. M. Gilbert for helpful suggestions throughout the investigation.

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MADISON, WISCONSIN.

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## EXPLANATION OF PLATES

All drawings were made with an Abbe camera lucida at table level. A Spencer 1.5 mm. achromatic objective, N.A. 1.25, and a Leitz 15 $\times$  ocular were used, giving a magnification of about 3000 times. Plate reduced one-fourth.

## PLATE 23

- Fig. 1. Stage in formation of basidial primordia.  
Fig. 2. Young basidium before the fusion of nuclei.  
Fig. 3. Basidium with large fusion nucleus.  
Fig. 4. Basidia showing various stages of first division; dark stained granules at poles.  
Fig. 5. Two-nucleate basidium.  
Figs. 6, 7, 8. Stages in second division.  
Fig. 9. Four-nucleate basidium.  
Fig. 10. nuclei in process of passing through sterigmata.  
Fig. 11. Basidium with extremely long sterigmata; nucleus in one spore in stage of division. (Note: The number for this figure was lost from the plate.)  
Fig. 12. Cross section of pseudoparenchymatous layer around peridiole.  
Fig. 13. Section of peridiole.

## PLATE 24

- Fig. 14. Section of undifferentiated fruiting body.  $\times 150$ .  
Fig. 15. Section of young carpophore showing early peridium differentiation and origin of cavities.  $\times 150$ .  
Fig. 16. Stage with zones of peridium shown; basidial primordia around cavities present.  $\times 150$ .  
Fig. 17. Section of older stage; outer zone of peridium sloughed off, inner pseudoparenchymatous; cavities lined with basidia; fundamental tissue split between the cavities.  $\times 150$ .

## PLATE 25

- Fig. 18. Cavity of the above enlarged.  $\times 650$ .  
Fig. 19. Cavity with early sterigmata and cavity formation.  $\times 650$ .

## PLATE 26

- Fig. 20. Enlarged portion of gleba of stage as fig. 16.  $\times 800$ .  
Fig. 21. Peridioles with pseudoparenchymatous covering.  $\times 650$ .

PLATE 23

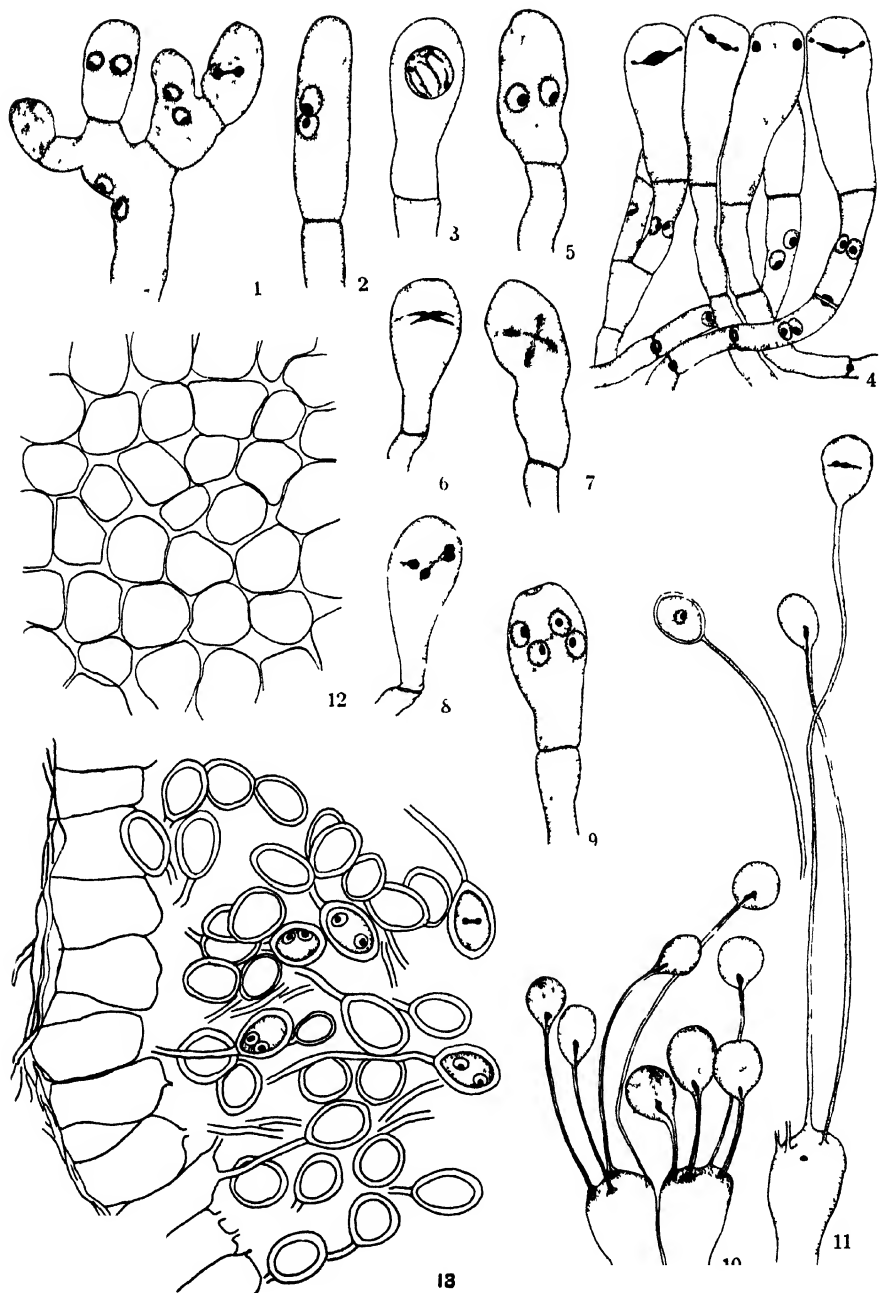






PLATE 24

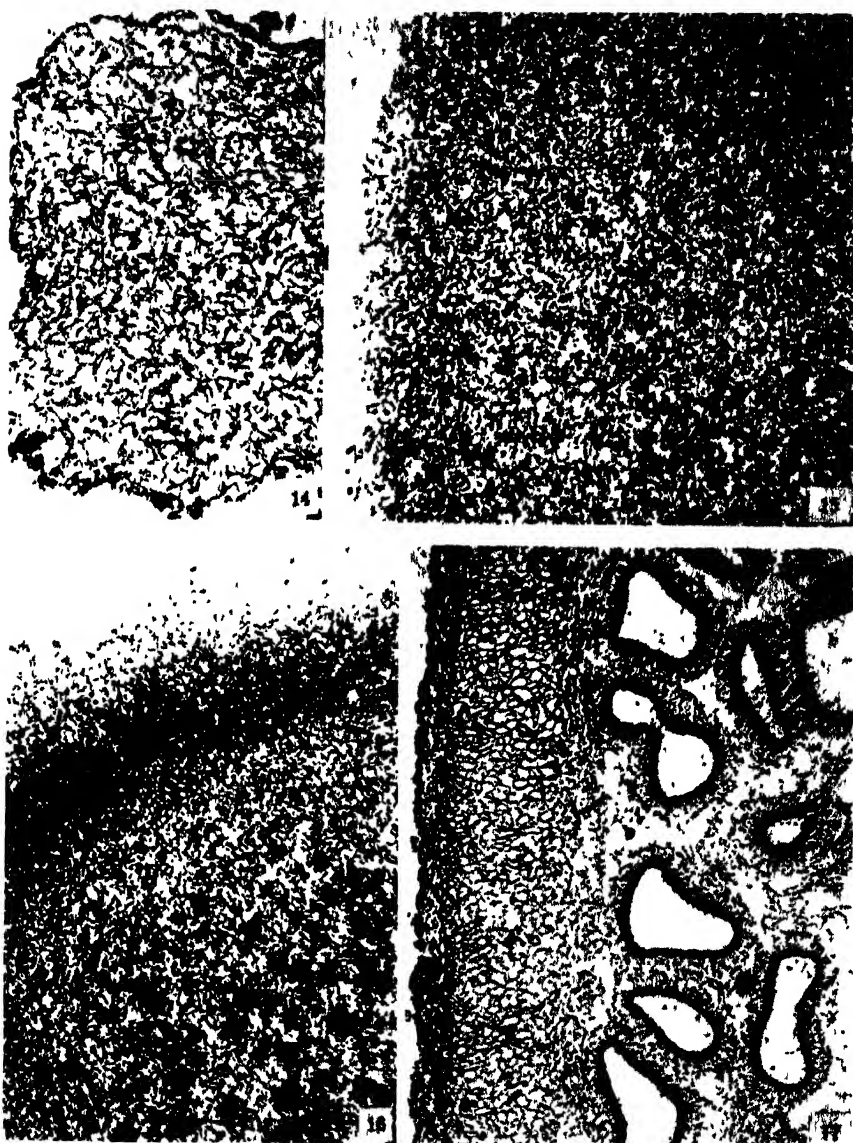




PLATE 25

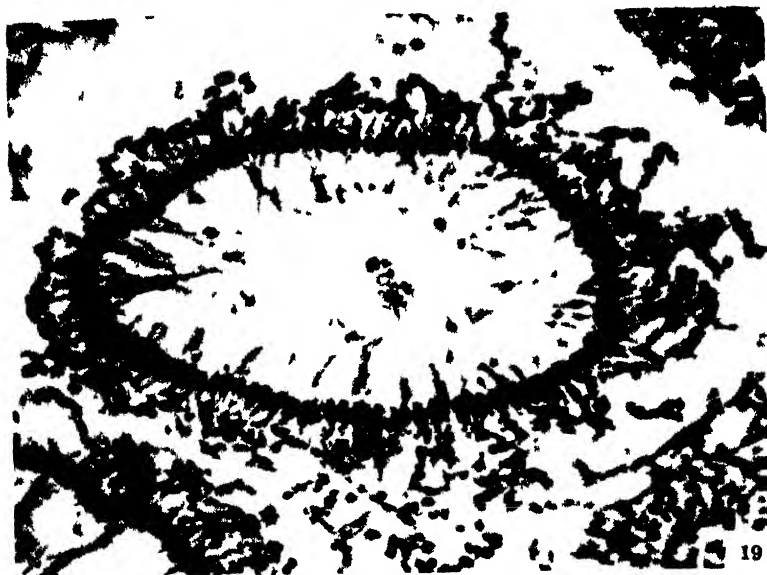
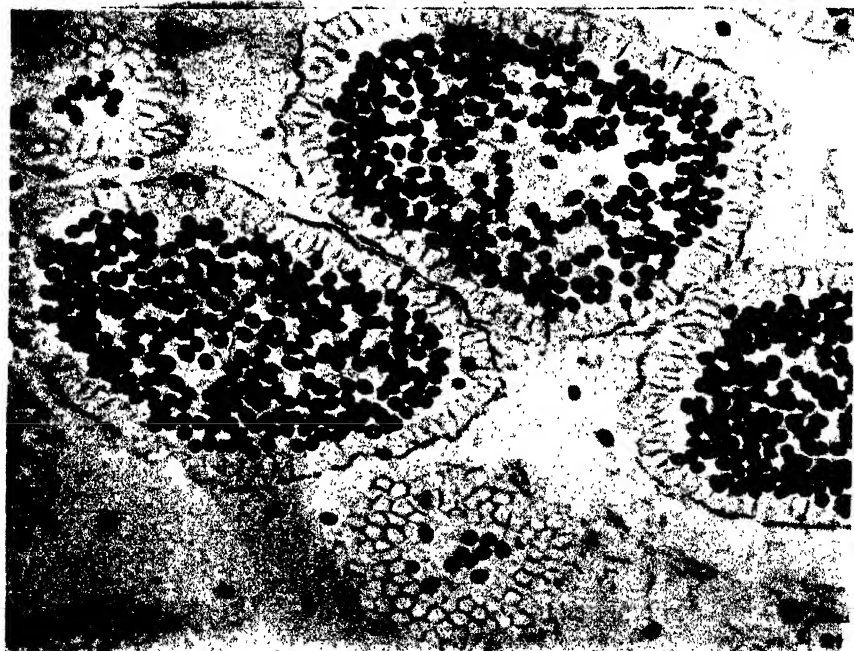
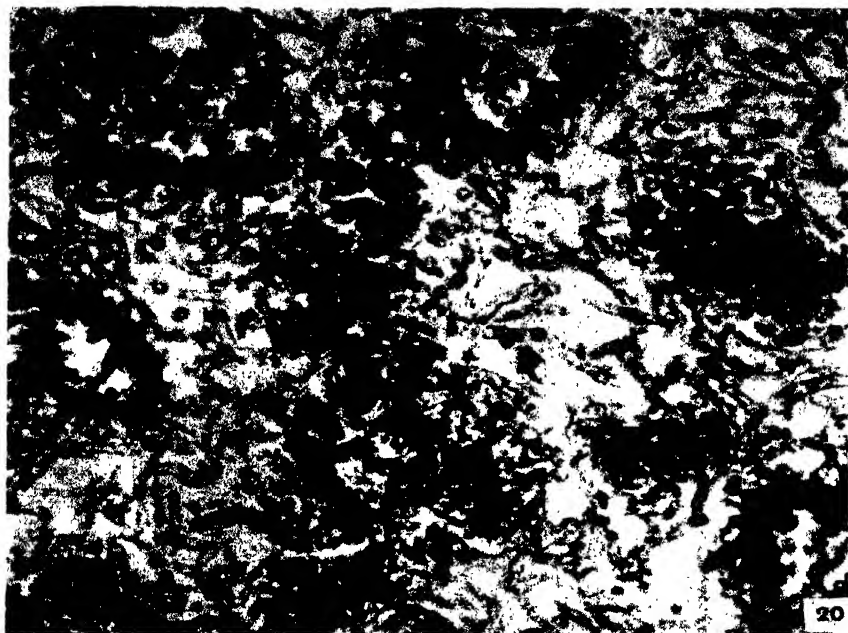




PLATE 26





# A TAXONOMIC AND MORPHOLOGICAL STUDY OF THE GENUS *CUSCUTA*, DODDERS, IN NORTH CAROLINA<sup>1</sup>

By BUDD ELMON SMITH

PLATES 27-31

## INTRODUCTION

In 1908 Peters worked out the seed development of two species of *Cuscuta*, *C. europaea* and *C. epithymum*. Miss MacPherson studied *C. Gronovii* in 1921, and her findings were included in a comparative study of *Cuscuta* and *Convolvulus*. Fedortschuk worked out the microsporogenesis and the macrosporogenesis of *C. epithymum* and *C. monogyna* in 1931. *Cuscuta lupuliformis* was studied by Asplund in 1920 and again by Dahlgren in 1927. Of the above mentioned species, *C. lupuliformis* and *C. monogyna* are European and Asiatic, *C. europaea* and *C. epithymum* are European. *Cuscuta Gronovii* is an American species, and *C. europaea* and *C. epithymum* have been introduced into America as common weeds.

In 1929 Miss Eliason prepared a few slides of *Cuscuta arvensis*, an American species, in connection with a more specific study that she was making on *Ipomoea purpurea* for a master's thesis in this university. These slides proved to be very interesting, and in 1931 Miss Henry was given the "Seed Development of *Cuscuta arvensis*" as an M.A. thesis problem. Neither of these theses has been published. In my study I have gone over *C. arvensis* again and have examined the seed development of other species, all native to North Carolina. This paper includes a taxonomic study of the seven species now known to occur in North Carolina: *C. arvensis* (= *pentagona*), *C. coryli*, *C. Gronovii*, *C. compacta*, *C. rostrata*, *C. indecora*, and *C. cephalanthi*, the last two here reported for the first time from the state. A study of the seed development in *C. arvensis*, *C. indecora*, *C. compacta*, *C. Gronovii*, and *C. rostrata* is also included. The work has brought to light several interesting peculiarities.

<sup>1</sup> A thesis submitted to the faculty of the University of North Carolina in partial fulfillment of the requirements for the degree of Master of Arts in the Department of Botany.



This work was suggested and done under the supervision of Dr. W. C. Coker to whom the writer wishes to express his sincere appreciation. To Misses Alma Holland, Velma Matthews, Mary Linda Vardell, Vera Millsaps, and Lily H. Schiele I wish to express my thanks for collections.

#### MATERIALS AND METHODS

Buds, flowers, and fruits of *Cuscuta arvensis* were collected September 20, September 28, Oct. 15, and Oct. 20, 1932, from the vicinity of Chapel Hill. These collections were supplemented by a collection of July 25, 1933, from Tryon, N. C. Some of these collections were placed in formalin-acetic-alcohol. Others were placed in medium chromo-acetic acid solution and others were placed in weak Flemming's fluid. The formalin-acetic-alcohol gave the best results and proved to be very useful since the time element was of no importance, i.e. I could collect material in the field and leave it in the fixative indefinitely. The formalin-acetic-alcohol material was taken from the fixative and placed in fifty per cent alcohol for several hours, and then treated in the usual way. The fifty per cent alcohol was changed several times to get rid of the acid and the formalin.

Buds, flowers, and fruits of *Cuscuta rostrata* were collected July 31, 1933, on Hogback Mt. near Tryon, N. C., and placed in formalin-acetic-alcohol where they remained until the fall. This collection was supplemented by collections from Mt. Mitchell and Blowing Rock, N. C.

Collections of *C. Gronovii* were made July 20, 1933, on the bank of Green River, Rutherford County, N. C., being fixed in the above manner. Other collections were made Oct. 5 and Oct. 20, from the vicinity of Chapel Hill, N. C.

*Cuscuta compacta* and *C. indecora* were collected and fixed June 25, July 10, 15, and 28, 1933, from the vicinity of the Piedmont Boy Scout Camp, Tryon, N. C.

All these were treated in the usual way and embedded in paraffin. Sections were cut 5, 7, 8, and 10 microns in thickness. These were stained in safranin-gentian violet, Heidenhain's iron alum haematoxylin, and Flemming's triple. They were mounted in balsam. I found that the Flemming's triple gave the best results.

Seeds were planted in the green house so that I might check the germination of them and study the seedlings.

#### SYSTEMATIC

Earlier placed in the order Polemoniales, Johnson (1931) with good reasons includes the family Convolvulaceae in the order Tubiflorales.

The characters of the order are a superior ovary, tubular or bilabiate corolla, usually a 2-carpellate pistil with various placentae, and usually numerous seeds.

The family includes 40-50 genera and about 1000 species (Johnson). This number includes herbs, shrubs, and trees of a wide distribution. They are found in the temperate zones and especially in the tropics. There are more representatives of this family in the tropics than any other family of the Sympetalae (Coulter and Chamberlain). The family may be characterized as follows:

Chiefly twining and trailing herbs which often contain milky juice. They have alternate leaves (or scales) and flowers of five stamens; a calyx of five imbricated sepals; 5-plaited, or five-lobed corolla, convolute or twisted in the bud, imbricate in *Cuscuta*. The ovary is 2-3-celled with a pair of erect ovules in each cell. Sometimes there are four cells due to false partitions. The embryo is large, coiled, embedded in a rather scanty, mucilaginous endosperm. The fruit is a 2-4-seeded capsule. The flowers are mostly large and showy, except in *Cuscuta* where they are small and always white. Articulated pedicels, often 2-bracted.

There is only one member of the family that is of much economic importance, *Ipomoea batatas*, the sweet potato. Many are cultivated for ornamental purposes. *Ipomoea pandurata*, the wild potato or old-man-of-the-earth is said to have been used as food by the Indians. On the other hand many of the family are looked on as pests, particularly the parasitic dodders. Several species of *Ipomoea* and *Convolvulus* are troublesome weeds.

The genus *Cuscuta* is composed of about 100 species. It consists of twining, leafless, parasitic annual and perennial herbs. They have yellow or orange twining stems, which attach themselves to the host and send haustoria into the tissue of the host plant. These stems vary in size, this being an important character in the identification of the species. When the seed germinates, the seedling has a very small root which lasts only for a short time. Soon the entire seedling, which is nothing but a little yellow string, is withdrawn from the seed and is severed from the ground by the drying up of the root. As soon as it emerges, the seedling commences a clockwise circular movement in search of a host. If it finds one it attaches itself promptly and begins its parasitic life.

Flowers have a perianth in two whorls of five or four lobes each. The stamens bear scale-like appendages at their base and these are very important in identification. The ovary is two-celled and four-ovuled. The styles are distinct and capitate or linear. The embryo is large and spirally coiled, without visible cotyledons. In most species there is a

preferred host, as *Alnus* for *C. compacta*, but in no case are they confined to these.

Choisy (1841) placed *Cuscuta* in the family Convolvulaceae. Engelmann (1842) approved this disposition but split the dodders into two genera, *Cuscuta* and *Lepidanche*. Later (1859), however, he dropped his genus *Lepidanche*. Today *Lepidanche* is used as a subsection of the genus *Cuscuta*. Pfeiffer (1846) and Des Moulins (1853) set up the dodders in a family of their own, the Cuscutaceae. In America this family is retained by Britton and Brown (1913) and by Small (1913, 1933), but Gray (1908) and Yuncker (1921) place the dodders in the Convolvulaceae.

Pfeiffer (l.c.) had proposed two new genera in the dodders, *Epilinella* and *Engelmannia*, but these have not been retained by subsequent students.

In 1921 Yuncker published a monograph on the North American and West Indian dodders. In this he described fifty-four species. Four were introduced from Europe, one from South America, and fourteen were new. Twenty-six species were found in the United States. Johnson (1931) recognizes only twenty-four species from the United States. Most of these according to Yuncker are found west of the Mississippi River.

### *The North Carolina Species*

There are seven species of the genus now known to occur in North Carolina, and I have collected all of them. Two of these (*C. cephalanthi* and *C. indecora*) have not before been reported in this state. Yuncker cites as the types of *C. rostrata* Shuttl. specimens from Little Craggy Mt., N. C. Des Moulins divided the genus into two tribes and all the species from this state are in the tribe Cuscutinene. The distinguishing character of the tribe is a non-circumscissile capsule. Yuncker indicates three subgenera. The North Carolina species belong to the subgenus *Grammica* and to the section *Clistogrammica*. This includes all the species which have a non-circumscissile capsule.

#### KEY<sup>1</sup>

Flowers not subtended by bracts; calyx more or less united.....Platycarpae  
Flowers subtended by numerous bracts; calyx mostly free.....Lepidanche

<sup>1</sup> Key adapted from Yuncker.

*Platycarpae*

Flowers membranous or fleshy, mostly pedicellate, usually without subtending bracts

Capsule globose or pointed, more or less depressed; scales present

Flowers smooth, not fleshy

Corolla at the base of the fruit; pentamerous.....*C. arvensis*

Corolla carried at the apex of the fruit; mostly tetramerous

*C. cephalanthi*

Flowers fleshy, tips of the corolla lobes inflexed

Flowers mostly tetramerous; scales rudimentary.....*C. coryli*

Flowers mostly pentamerous, 2-4 mm. long; scales prominent

*C. indecora*

Capsule globose-ovoid or long-beaked; scales prominent; flowers large, pentamerous

Capsule flask-shaped with a long neck.....*C. rostrata*

Capsule globose-ovoid or conic, 3-5 mm. wide; styles at least one-third the length of the capsule.....*C. Gronovii*

*Lepidanche*

Flowers sessile in compact clusters with many subtending bracts

Bracts obtuse, closely appressed.....*C. compacta*

*Cuscuta arvensis* Beyrick

(Pl. 27, Figs. 1-6)

*C. pentagona* Engelm.

*Epithymum arvense* (Beyrick) Nieuwland and Lunell

Stems slender. Flowers 3-5 mm. in length, smooth, pentamerous, on pedicels which are short. Flowers in dense clusters; calyx lobes obtuse and spreading. Scales prominent, deeply fringed and often reaching the summit of the corolla tube. Corolla broad, lobes longer than the tube, the latter spreading. Stamens shorter than the lobes of the corolla, usually yellowish in color; anthers elliptical, shorter than the filaments; styles longer than the ovary. Capsule globose and depressed with the corolla remaining around the base of the mature fruit. Seeds usually four to the capsule.

Locality: Entire state, introduced from Europe. Collections from Tryon, Hillsboro, Elizabeth City, Chapel Hill, and Benson, N. C.

Hosts: Legumes and composites. Commonly called the "clover dodder."

*Cuscuta cephalanthi* Engelm.

(Pl. 27, Figs. 7-9)

Medium yellow stems. Very small tetramerous flowers, 2-4 mm. long. Calyx short and deeply divided; corolla cylindrical campanulate, lobes ovate and spreading. Scales prominently fringed. Stamens about equalling the corolla lobes; anthers round and oval. Styles about equal to the globose and depressed ovary. Corolla persists as the cap of the fruit. Seeds small.

Locality: Chapel Hill, N. C., on asters.

Hosts: Grows on herbs and shrubs.

*Cuscuta coryli* Engelm.

(Pl. 27, Figs. 10-12)

*C. compacta crenulata* Choisy

*C. inflexa* Engelm.

*C. congesta* Beyrick

*C. parviflora* Nuttall

*C. umbrosa* Beyrick

*Epithymum coryli* (Engelm.) Nieuwland and Lunell

Slender and medium-sized, pale yellow stems. Flowers small, 3-4 mm. long, mostly tetramerous, pedicellate, and in paniced cymes. Calyx lobes triangular and the acute tips often inflexed. Rudimentary scales. Stamens about as long as the lobes and the anthers are oval-oblong. The ovary is globose and thickened toward the apex; the stigma is capitate. Corolla may remain about the fruit for a while, not an essential character.

Locality: Chapel Hill, N. C.

Hosts: *Corylus*, *Bignonia*, and *Tecoma*.

*Cuscuta indecora* Choisy

(Pl. 27, Figs. 13-16)

*C. decora* Engelm.

*Epithymum indecorum* (Choisy) Nieuwland and Lunell

Stems medium and pale yellow. Flowers are very small, not exceeding 4 mm. and usually under 3 mm. Gamosepalous calyx. Corolla lobes are triangular and have inflexed tips. The scales are small and deeply fringed; sometimes they cover the top of the globular, pointed

ovary. The withered corolla envelopes the ovary. The stigma is capitate. Flowers were first found blooming July 20, 1933.

Locality: Tryon, N. C., Piedmont Boy Scout Camp on Lake Lanier. This is the first record of this species in North Carolina.

Hosts: Legumes and asters.

*Cuscuta rostrata* Shuttleworth

(Pl. 27 Figs. 17-20)

*C. oxycarpa* Engelmänn

Stems coarse and brilliantly coral colored. This is the common mountain dodder. Flowers are larger than those of any other species, 6-8 mm. long, pentamerous, pedicellate, in paniced cymes. Calyx shorter than the corolla tube; lobes ovate and overlapping. Corolla membranous; lobes broad, spreading, and becoming reflexed at maturity. Scales deeply fringed. Stigmas capitate, and styles long and slender. Ovary flask-shaped and enveloped by the withered corolla. Anthers oval.

Locality: Mountains of the western part of the state. Collections from Tryon, Mt. Mitchell, Blowing Rock, Bryson City, Nantahala Gorge, Craggy Mt., Roan Mt., Bald Mts., Hogback Mt., and Highlands, N. C.

Hosts: Tall herbs, and shrubs, as aster, nettle and hydrangeas.

*Cuscuta Gronovii* Willdenow

(Pl. 27, Figs. 21-23)

*Epithymum Gronovii* (Willd.) Nieuwland and Lunell

Stems coarse, pale yellow to coral. Flowers medium, 4-5 mm. long, glabrous, usually in loose cymes. Corolla lobes shorter than the tube, lobes spreading and obtuse. Calyx gamosepalous; lobes broad and overlapping. Stigmas capitate. Scales greatly fringed. Capsule globose, frequently beaked and enveloped by the withered corolla.

Locality: Collections from Rutherford, Johnston, Orange, and Polk counties, N. C. This is the most common species around Chapel Hill.

Hosts: *Polygonum*, nettles, composites, and other tall herbs.

*Cuscuta compacta* Jussieu

(Pl. 27, Figs. 24-27)

*C. acaulis* Rafinesque

*C. remotiflora* Bertolonia

*C. fruticum* Bertolonia

*C. compacta adpressa* Engelmann

*C. coronata* Beyrick

*C. imbricata* Nuttall

*C. americana*

*Lepidanche adpressa* Engelmann

Stems coarse and of a pale yellow color. Flowers medium in size, 4-5 mm. long, sessile, and in very compact clusters. Calyx polysepalous, surrounded by 2-4 bracts very similar to the sepals themselves. Corolla lobes spreading from a cylindrical tube, their tips just exerted above the calyx. Stamens shorter than the lobes of the corolla. Styles capillary and the stigma capitate. Ovary globose-conical, as is the mature fruit. The withered corolla is carried at the apex of the fruit.

Locality: Throughout the state. Collected in Jackson, Johnston, Perquimans, Buncombe, Swain, Polk, and Haywood counties. This is the most common species in North Carolina.

Hosts: *Alnus* and *Eupatorium*. Sometimes on oaks and other trees. Commonly called the "alder dodder."

#### DEVELOPMENT OF THE SEED

##### *The ovary and the ovule*

The ovary of *Cuscuta arvensis* is two-celled, as is the ovary of the other species studied (Fig. 28). Each of the cells contains two anatropous ovules. There is a single massive integument in each of the species studied which is in accord with the work of Fedortschuk and Peters (Fig. 29). The integument starts its growth very early. It grows rapidly as shown in figures 30a, 30b, and 30c. The presence of the anticlinal walls shows that the cells of the integument are growing up over the small nucellus. There are some cells in this section that show recent division (Fig. 32). Starch is abundant in the cells of the integument at all times after the four-celled stage of the embryo-sac is reached. There are certain large cells in the integument that do not contain starch. These will be taken up later and discussed. In the majority of the ovules that have been examined there were found tracheids extending far up into the integument of the ovule (Figs. 30b and 31). Miss Nell Henry, working in this laboratory, had noted them the preceding year. Such an extension of tracheids into the young ovule beyond the chalaza is very unusual. As long ago as 1872, Van Tieghem described the extensive tracheal development in the ovules and seeds of a number of

genera (Cucurbitaceae, *Acacia*, *Diospyros*, *Syringa*, *Symphoricarpos*, etc.), but it is not clear to us in which he refers to ovules and in which to mature seeds. Striking cases of tracheal development in the ovule were reported in *Acacia* by Guignard (1881, p. 28), and in *Casuarina* (Treub, 1891) where tracheids are found even in the archesporial region. For *Mimosa*, see Le Monnier (1872). In *Castanea* (Benson, 1894) and in *Asclepias* (Frye, 1902) isolated tracheids are found beneath the embryo-sac. Being interested to find if such cells appeared in the young ovules of other members of the family, I made sections of *Ipomoea purpurea* and found them there even more extensively prolonged into the integument (Figs. 33a and 33b).

When the ovule is very young large cells, varying greatly in number, appear in the integument, usually about six layers of cells below the surface of the ovule (Fig. 34). They have brilliantly staining nuclei which are embedded in the peripheral protoplasm (Figs. 35a and 35b). At no time do they contain starch as do the surrounding cells of the integument. These are more common in *C. arvensis* than in any of the other species examined. In one they did not occur at all. These cells grow in size up to the time of fertilization and as soon as this is accomplished they begin to collapse and soon disappear completely.

#### *The embryo-sac*

When the ovule is very young one large hypodermal cell appears which has a large nucleus, a deeply staining nucleolus, and dense cytoplasm (Fig. 36). This is the megaspore-mother-cell which is embedded in the center of the minute nucellus which consists of only one row of cells around the mother-cell (Fig. 29). The nucellar cells are used up by the developing embryo-sac very early. By the time that the sac is ready for fertilization there is no nucellus left, and the inner cells of the integument are being used for nourishment (Fig. 39). The origin and early disappearance of the nucellus seems to be characteristic for the family. Peters reports a tapetum in *C. lupuliformis* and *Convolvulus sepium*. Asplund (1920) believes Peters is right, due to his own experiments on *C. lupuliformis*. Dahlgren (1927) concludes that tapetal tissue has been found with certainty in *Plumbaginaceae* and *Cucurbitaceae* of the *Sympetaleae*. It appears that it is also present in *Viburnum* but this is not certain. Dahlgren shows photographs of *Cuscuta lupuliformis* showing no tapetum and he doubts the accuracy of the conclusions of Peters and Asplund. I find no tapetum in any of the five species examined. The case of coffee is also confusing, as Faber (1912) shows



some figures with a deeply seated archesporium and another with the mother-cell touching the epidermis. This is discussed by Dahlgren (page 392). In order to explain these discrepancies he states that the mother-cell may have destroyed all the cells between it and the epidermis even before the first division.

In *Cuscuta* the cells of the nucellus are hexagonal when the archesporial cell makes its first appearance but very soon they become elongated. The cells of the surrounding integument are always hexagonal, and the cytoplasm is less dense than that in the nucellar cells. At no time after the differentiation of the archesporium cell is it hard to recognize. Very soon the mother cell begins to elongate. Nuclear divisions follow, resulting in a tetrad of potential megaspores. Very soon the upper (micropylar) three of these begin to degenerate leaving the lower one to form the embryo-sac (Fig. 32). This is in accord with the work of Peters on *C. epithymum* and *C. europaea*, and Fedortschuk on *C. epithymum* and *C. monogyna*. The developing megaspore enlarges rapidly and soon nuclear divisions occur, resulting in the normal angiospermous sac (Fig. 39). The sac increases greatly in length, 40–80 $\mu$  in the uninucleate stage. This rapid growth continues until fertilization. As soon as the first division occurs the nuclei show polarity (Fig. 37). The second division is as in figure 38. The three divisions are shown in figure 39. Here we see clearly the three antipodals which very early disappear. The polars migrate to a position about the center of the sac and remain there. The egg apparatus is as usual (Fig. 40).

#### *Fertilization*

I have not observed fertilization in *Cuscuta arvensis*, but have seen the distal end of the pollen tube attached in some species examined (Fig. 41). It degenerates very early, according to Fedortschuk, and at all times is almost invisible. The tube is extremely small as compared to the very large one in *Ipomoea purpurea*. The embryo-sac is probably ready for fertilization early in the morning when the flowers first open, for sections from material that was collected at 8 A.M. showed the polar nuclei near the center of the sac and near each other (Fig. 40). The synergids soon disappear after fertilization, and there is a wall formed around the egg.

#### *The embryo*

The first division of the zygote is always transverse (Fig. 42). Usually the distal cell is smaller than the basal cell. Both cells have large

nuclei. The second cell soon becomes enlarged and vacuolated. The second division occurs in the basal cell only and is perpendicular to the first division (Fig. 43). Either of these cells is larger than the original distal cell. There are no fixed planes of division from this point on. These divisions result in an embryo which has a many-celled suspensor (Fig. 45), but the embryo proper is urn-shaped. The shape of the embryo varies for the different species, but not a great deal. The suspensor cells are vacuolated. Well developed suspensors have been reported for all species of *Cuscuta* studied. The mature embryo is much coiled. Coulter and Chamberlain (1904) report the embryos of *Cuscuta* and *Viscum* as unusual for parasites because they are so well developed.

#### *The endosperm*

The upper and the lower polar nuclei fuse to form the fusion nucleus, which comes to rest about the center of the sac. According to Fedortschuk the second sperm fuses with the primary endosperm nucleus to form the definitive endosperm nucleus, but I have not observed this. Very soon the endosperm nucleus divides and division keeps up until as many as 225-250 free endosperm nuclei can be counted for a single sac. It seems that the first division of the zygote and the first division of the endosperm nucleus is about simultaneous. By the time the first division of the egg is complete there may be as many as ten free endosperm nuclei (Fig. 44). This exceptionally large number of free endosperm nuclei is unusual for parasites (Coulter and Chamberlain), and is not stressed by any previous workers except Miss Henry. Finally walls are formed very rapidly to form the cellular endosperm which surrounds the urn-shaped embryo (Fig. 46).

#### *The mature seed*

The seed coat, which consists entirely of integumental tissue, is differentiated into several layers. The outer layer, one cell thick, is composed of large thin-walled cells containing starch. Beneath this are two layers of elongated narrow cells with large nuclei and hard walls. Next within is a mass of about twelve layers of large thin-walled cells containing starch. Separating the embryo from the seed coat there is scanty endosperm.

Miss MacPherson describes perisperm for *Convolvulus sepium*, but we are compelled to doubt the accuracy of this observation. In all other members of the family studied, the nucellus is minute and quickly disappears, and it is hardly probable that *Convolvulus* is an exception to this rule.

*Cuscuta compacta*

The ovary and the ovule of this species do not differ from the other species just described. In the nucellus there is a difference in that it is more prominent (Fig. 48). The nucellus extends above the very young integument. In the other species the nucellus is not so prominent. The usual hypodermal archesporium appears and soon the tetrad of megaspores is formed, and the lower one functions. The embryo and the endosperm develop as in *C. arvensis*.

*Cuscuta Gronovii*

In 1921 Miss MacPherson published an account of *C. Gronovii* which caused a reinvestigation due to some figures that were not clear.

The ovary and the ovule of this species is as described for *C. arvensis*, except that there are fewer of the resin cells. The development of the embryo-sac is normal. Miss MacPherson does not mention the origin of the archesporium, but it is as usual and is developed from the hypodermal cell which is embedded in the minute nucellus. The regular tetrad is formed. The antipodals of the embryo-sac are used up very early and leave only the centrally located polars and the egg apparatus. The nucellus is used up very early and then the integument cells furnish nourishment for the developing sac (Fig. 49). At all times the embryo-sac is clearly defined in its outline, which is not shown by Miss MacPherson. Fertilization was not observed. The embryo develops as in the other dodders, but it is more urn-shaped (Fig. 50). The endosperm arises from the free nuclear divisions and is always very scanty. The mature seed is as usual.

*Cuscuta indecora*

This species does not vary a great deal from *C. arvensis* and the other species examined. The development of the embryo-sac in the anatropous ovules is as usual (Fig. 51). There are *none* of the resin cells present in the integument of the ovule. The tracheids are present. The development of the embryo and the structure of the mature seed are as described for the others.

*Cuscuta rostrata*

Seed development in this species has never been described and I find some variation from the usual details. The development of the embryo-sac is as above, and all the steps are alike until we get to the first division of the zygote. The first division is as before as to being trans-

verse, but instead of a large and a small cell the two cells are of the same size. The second division does not occur in the basal cell alone but in the distal cell, too. The division is perpendicular to the first. This gives the proembryo of four cells, equal in size. As before, the development from this point on has no fixed plane of division (Fig. 54). There is a massive suspensor and the usual type of embryo. There are many more free endosperm nuclei in this species than in *C. arvensis*. By actual count there were 1549 free endosperm nuclei in one sac. At this time the embryo was as in figure 55. Figure 56 is a section showing the numerous nuclei embedded in the peripheral cytoplasm. Other developments are as above.

#### FLORAL DEVELOPMENT

In the floral development of the flower the dodders examined are identical. There is an acropetalous development as follows: sepals, petals, stamens, and the pistil. These parts are all protected by a heavy bud scale (Fig. 57). In the stamen very early sporogenous tissue is differentiated, as is usual for the *Sympetalae*. From the base of the stamens a scale is formed which varies in shape and size for the different species. The shape of the ovary also varies in the species studied. In some there is a long beak and in others they are simply globose and in most cases are depressed.

#### THE MICROSPORANGIUM

The young microsporangium shows a wall of two or three layers of cells, one tapetal layer, and a central mass of definitive archesporial cells (Fig. 60).

#### *The microspore-mother-cell and its division*

The microspore-mother-cells are typical in the resting stage, containing a large nucleus and much cytoplasm. The latter usually forming rays from the centrally located nucleus to the cell wall. There is never more than one nucleus in these cells and never more than one nucleolus, as far as observations have shown. The nuclear divisions are very rapid. Before the spindle of the first division is gone the second is complete, and as a result we have a network of spindles (Fig. 65). Very soon the cytoplasm of the mother cell begins to collect around the nuclei and four microspores are promptly formed. Most of the spores are arranged in the usual tetrad fashion, but it is not uncommon to find all four in one plane. The mother-cell wall now disappears and the micro-

spores are free in the sporangial cavity. Immediately, it seems, they arrange themselves around the periphery of the cavity, next to the nourishing tapetum.

#### THE MALE GAMETOPHYTE

The microspores now rapidly acquire the general shape and characteristic markings of the mature pollen grain, growing greatly in size (Fig. 69). The single nucleus soon divides to form the generative and the tube nucleus (Fig. 71). There are seven haploid chromosomes (Fig. 70). Different phases in the mitosis of the spore are seen in figures 69 and 70. These findings are in accord with those of Fedortschuk for *C. epithymum* and *C. monogyna*. The generative nucleus soon divides to form the two male nuclei. A spindle at right angles to the first is seen (Fig. 74). The male nuclei are formed before the shedding of the pollen. No abnormal cases have been observed, except in some cases where there were only two instead of four spores formed from a mother cell. There are never more than two male nuclei as far as observations have shown. Fedortschuk reports more in some cases.

The exine of the mature pollen grain is very thick, being marked by pits. The thickenings of the exine have characteristic markings as shown in figure 77.

Not all the microspores function. Many were seen in a collapsed state and the nuclei were going to pieces, even before the opening of the pollen sac.

The findings for all the species were alike as stated above. The pollen grains of the different species vary from about 16–24 $\mu$  in *C. compacta* to 25–30 $\mu$  in *C. Gronovii*.

#### SUMMARY

1. There are seven species of the genus *Cuscuta* in North Carolina: *C. arvensis*, *C. compacta*, *C. cephalanthi*, *C. coryli*, *C. Gronovii*, *C. indecora*, and *C. rostrata*. *Cuscuta cephalanthi* and *C. indecora* are here reported for the first time from the state.

2. The archesporium has an hypodermal origin and develops at once into a tetrad of megaspores, with the lower one functioning as the embryo-sac.

3. A well developed strand of tracheids extends from the funiculus up into the ovule. They are also found in *Ipomoea*. Conspicuous resin cells appear in the integument of the ovule. Exception—*Cuscuta indecora*.

4. The development of the embryo-sac is as usual. The egg apparatus, the antipodals, and the polars were observed. The antipodals disappear very early.

5. There is a single massive integument, no tapetum, and a minute nucellus which entirely disappears by the time of fertilization. (According to Coulter and Chamberlain the presence of a single integument and the absence of parietal tissue is universal for the *Sympetalae*.)

6. Pollen tubes were observed, but fertilization was not.

7. The first division of the fertilized egg is transverse. The resulting cells are unequal in size, and the second division is perpendicular to the first and occurs in the basal cell only. *Cuscuta rostrata* differs here in that the first division gives rise to two cells of equal size, and the second division occurs in both cells.

8. The first division of the primary endosperm nucleus occurs about the time the first division of the zygote takes place, and initiates the formation of a great number of free endosperm nuclei.

9. The mature embryo is large and well developed. The mature embryo is surrounded by the scanty endosperm.

10. The seed coat is made up of three distinct layers, the inner of which contains much starch.

11. The microsporangium develops as usual. The wall of the sporangium has four layers of cells: three wall layers and a nutritive tapetal layer.

12. The microspore tetrad is developed in the usual way. Spindles persist for a time in the division of the microspore-mother-cell.

13. There are many microspores that do not function i.e., they do not develop.

14. The generative nucleus divides to form the two male nuclei before the shedding of the pollen.

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## PLATE 27

## CUSCUTA ARVENSIS

## Figs. 1-6

- Fig. 1. Habit sketch of the plant growing as a parasite on *Lespedeza*.  $\times \frac{1}{2}$
- Fig. 2. Open flowers.  $\times 4\frac{1}{2}$ .
- Fig. 3. Longitudinal section of a flower.  $\times 4\frac{1}{2}$ .
- Fig. 4. Opened corolla tube showing the scales at the base of the stamens.  $\times 4\frac{1}{2}$ .
- Fig. 5. Mature fruit with the withered corolla at its base.  $\times 4\frac{1}{2}$ .
- Fig. 6. Mature seed.  $\times 4\frac{1}{2}$ .

## CUSCUTA CEPHALANTHI

## Figs. 7-9

- Figs. 7a and 7b. Open flower.  $\times 4\frac{1}{2}$ .
- Figs. 8a, 8b, and 8c. Corolla opened to show the scales. Note the variable number of the petals.  $\times 4\frac{1}{2}$ .
- Fig. 9. Mature fruit.  $\times 4\frac{1}{2}$ .



## CUSCUTA CORYLI

## Figs. 10-12

Fig. 10. Open flower.  $\times 4\frac{1}{2}$ .

Fig. 11. Corolla opened to show the scales.  $\times 4\frac{1}{2}$ .

Fig. 12. Mature fruit.  $\times 4\frac{1}{2}$ .

## CUSCUTA INDECORA

## Figs. 13-16

Fig. 13. Habit sketch.  $\times \frac{1}{2}$ .

Fig. 14. Open flower.  $\times 4\frac{1}{2}$ .

Fig. 15. Open corolla showing scales and inflexed corolla lobes.  $\times 4\frac{1}{2}$ .

Fig. 16. Mature fruits.  $\times 4\frac{1}{2}$ .

## CUSCUTA ROSTRATA

## Figs. 17-20

Fig. 17. Habit sketch. Parasite on nettle.  $\times \frac{1}{2}$ .

Fig. 18. Open flower.  $\times 4\frac{1}{2}$ .

Fig. 19. Open corolla showing the scales.  $\times 4\frac{1}{2}$ .

Fig. 20. Mature fruit.  $\times 4\frac{1}{2}$ .

## CUSCUTA GRONOVII

## Figs. 21-23

Fig. 21. Mature fruit.  $\times 4\frac{1}{2}$ .

Fig. 22. Open flowers.  $\times 4\frac{1}{2}$ .

Fig. 23. Open corolla showing the scales.  $\times 4\frac{1}{2}$ .

## CUSCUTA COMPACTA

## Figs. 24-27

Fig. 24. Habit sketch. Parasite on *Alnus*.  $\times \frac{1}{2}$ .

Fig. 25. Open flowers. Sessile.  $\times 4\frac{1}{2}$ .

Fig. 26. Open corolla showing the scales.  $\times 4\frac{1}{2}$ .

Fig. 27. Almost mature fruit with the persistent corolla.  $\times 4\frac{1}{2}$ .

## PLATE 28

## CUSCUTA ARVENSIS

## Figs. 28-32, 34, 35

Fig. 28a. Longitudinal section through the flower showing the arrangement of the flower parts, the tracheids, and the ovules.  $\times 35$ .

Fig. 28b. Mature embryo.  $\times 5$ .

Fig. 29. Young ovule showing the minute nucellus, the megaspore mother-cell, and the integument.  $\times 325$ .

Fig. 30a, b, c. Longitudinal sections of ovules showing the different stages in the growth of the massive integument.  $\times 143$ .

Fig. 31. Tracheids taken from the section shown in figure 30b.  $\times 650$ .

Fig. 32. Young ovule showing the nucellus, the integument, and the four megaspores with the lower one functioning.  $\times 325$ .

Fig. 33a. Ovule of *Ipomoea purpurea* showing the well developed tracheids.  $\times 35$ .

Fig. 33b. Enlarged portion of an ovule showing the tracheids in the integument of *I. purpurea*.  $\times 287$ .

Fig. 34. Longitudinal section of an ovule showing gum cells.  $\times 67$ .

Fig. 35a, b. Gum cells, enlarged.  $\times 650$ .

#### PLATE 29

##### *CUSCUTA ARVENSIS*

Fig. 36. Megaspore mother cell.  $\times 287$ .

Fig. 37. 2-nucleate embryo-sac with the nucellar tissue beginning to break down.  $\times 650$ .

Fig. 38. 4-nucleate embryo-sac with the nucellus almost used up.  $\times 650$ .

Fig. 39. 8-nucleate embryo-sac with the nucellus completely used up, and the integument cells are being used as food.  $\times 650$ .

Fig. 40. Micropylar end of embryo-sac ready for fertilization.  $\times 325$ .

Fig. 41. Pollen tube in embryo-sac.  $\times 325$ .

Fig. 42. First division of the embryo.  $\times 650$ .

Fig. 43. Longitudinal section through the embryo-sac showing the second division of the embryo and the free endosperm nuclei.  $\times 650$ .

Fig. 44a. Young embryo of several cells.  $\times 325$ .

Fig. 44b. Section from ovule of figure 44a showing the great number of free endosperm nuclei.  $\times 325$ .

Fig. 45. Old embryo.  $\times 325$ .

Fig. 46. Embryo embedded in the endosperm.  $\times 67$ .

Fig. 47. Portion of the wall of a mature seed.  $\times 325$ .

#### PLATE 30

Fig. 48. Young ovule of *C. compacta* showing nucellus and archesporium.  $\times 325$ .

Fig. 49. Embryo-sac of *C. Gronovii*. Nucellus has been used up. Polar nuclei are approaching each other.  $\times 650$ .

Fig. 50. Embryo in cellular endosperm of *C. Gronovii*.  $\times 143$ .

Fig. 51. Young ovule of *C. indecora* showing tetrad of megaspores, the nucellus, and the integument.  $\times 325$ .

Fig. 52. Longitudinal section of an embryo-sac of *C. indecora* with a young embryo and free endosperm nuclei.  $\times 80$ .

Fig. 53. Young ovule of *C. rostrata*. Degenerating megaspores, nucellus, and integument.  $\times 650$ .

Fig. 54. Four-celled embryo and mitosis of the second division.  $\times 325$ .

Fig. 55. Young embryo and free endosperm nuclei.  $\times 67$ .

Fig. 56. Longitudinal section through same ovule as figure 55, showing free endosperm nuclei.  $\times 67$ .

Fig. 57. Flower bud showing bud scale, calyx, corolla, calyx, stamens, pistil, and scales.  $\times 35$ .

#### PLATE 31

Fig. 58. Longitudinal section of a young anther showing two sporangia.  $\times 192$ .

Fig. 59. Cross section of a young anther showing four sporangia.  $\times 192$ .

Fig. 60. Enlarged young sporangium showing wall layers, tapetum, and the sporogenous cells.  $\times 382$ .

- Fig. 61. Microspore-mother-cell.  $\times 867$ .  
Fig. 62. Nucleus of microspore-mother-cell in prophase.  $\times 867$ .  
Fig. 63. Nucleus of microspore-mother-cell in spireme stage.  $\times 867$ .  
Fig. 64. First mitosis of the microspore-mother-cell.  $\times 867$ .  
Fig. 65. Second mitosis.  $\times 867$ .  
Fig. 66. Second mitosis.  $\times 867$ .  
Fig. 67. Tetrad of microspores in mother cell.  $\times 867$ .  
Fig. 68. Tetrad of microspores in mother cell.  $\times 867$ .  
Fig. 69. Microspore showing metaphase of first division of nucleus.  $\times 867$ .  
Fig. 70. Anaphase of first division.  $\times 867$ .  
Fig. 71-73. 2-nucleate microspores.  $\times 867$ .  
Fig. 74. Metaphase of second division of the microsporé.  $\times 867$ .  
Fig. 75. Telophase of the second division.  $\times 867$ .  
Fig. 76. Completion of the second mitosis.  $\times 867$ .  
Fig. 77. Mature pollen grain with two male nuclei and the tube nucleus.  $\times 867$ .

# PLATE 27

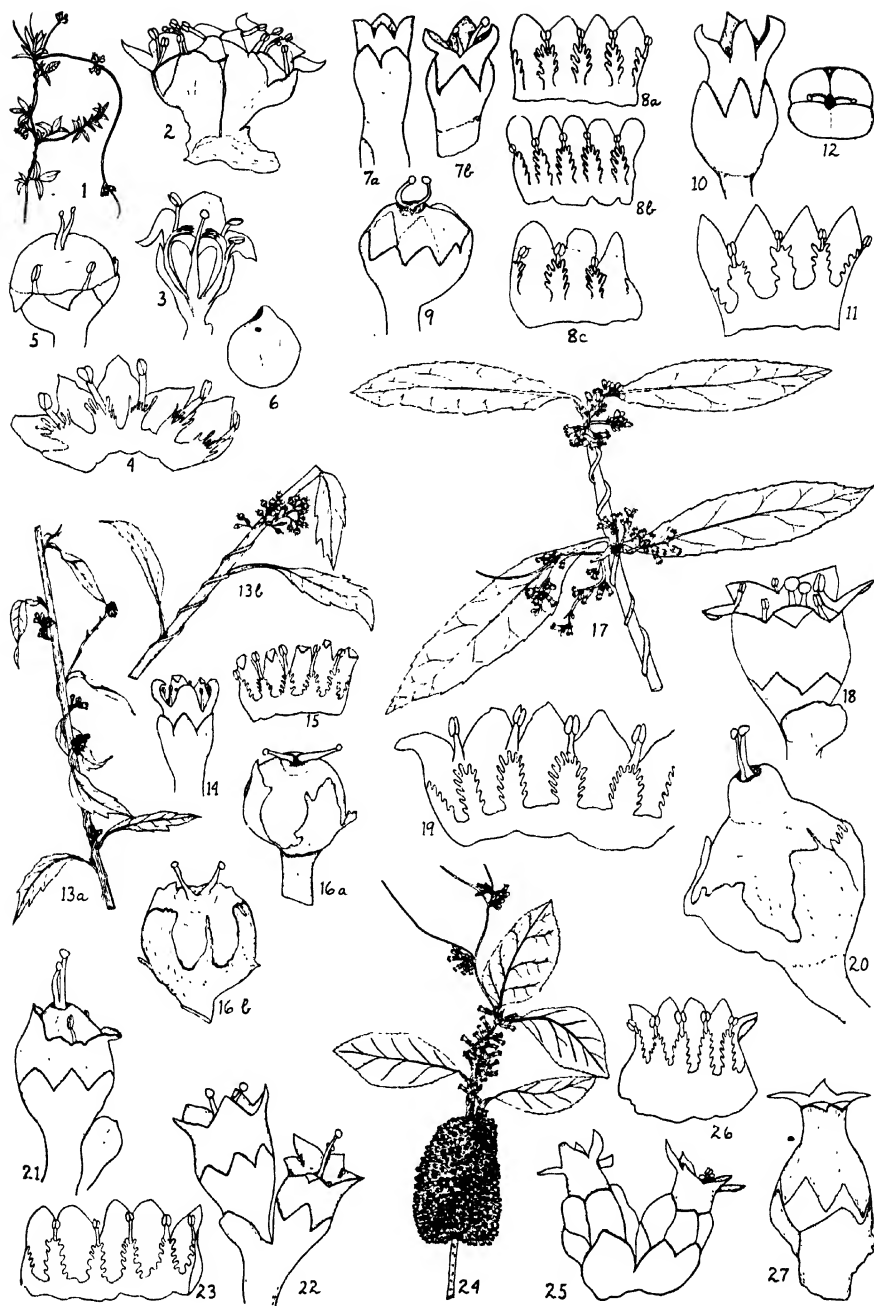




PLATE 28

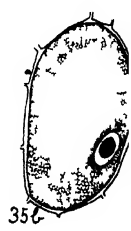
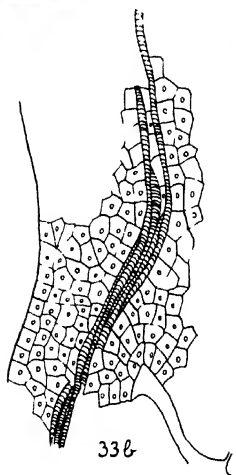
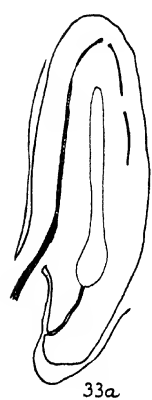
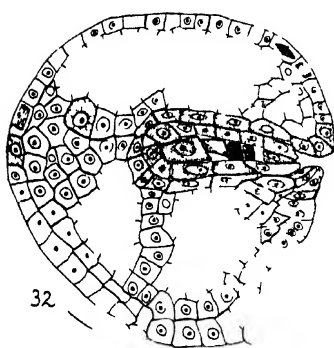
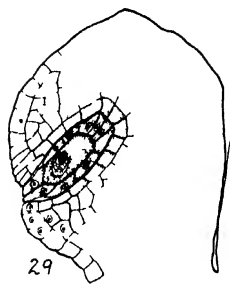
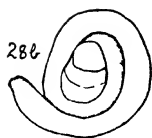
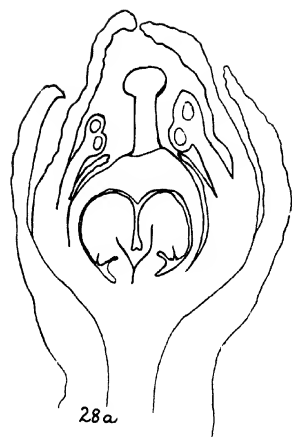
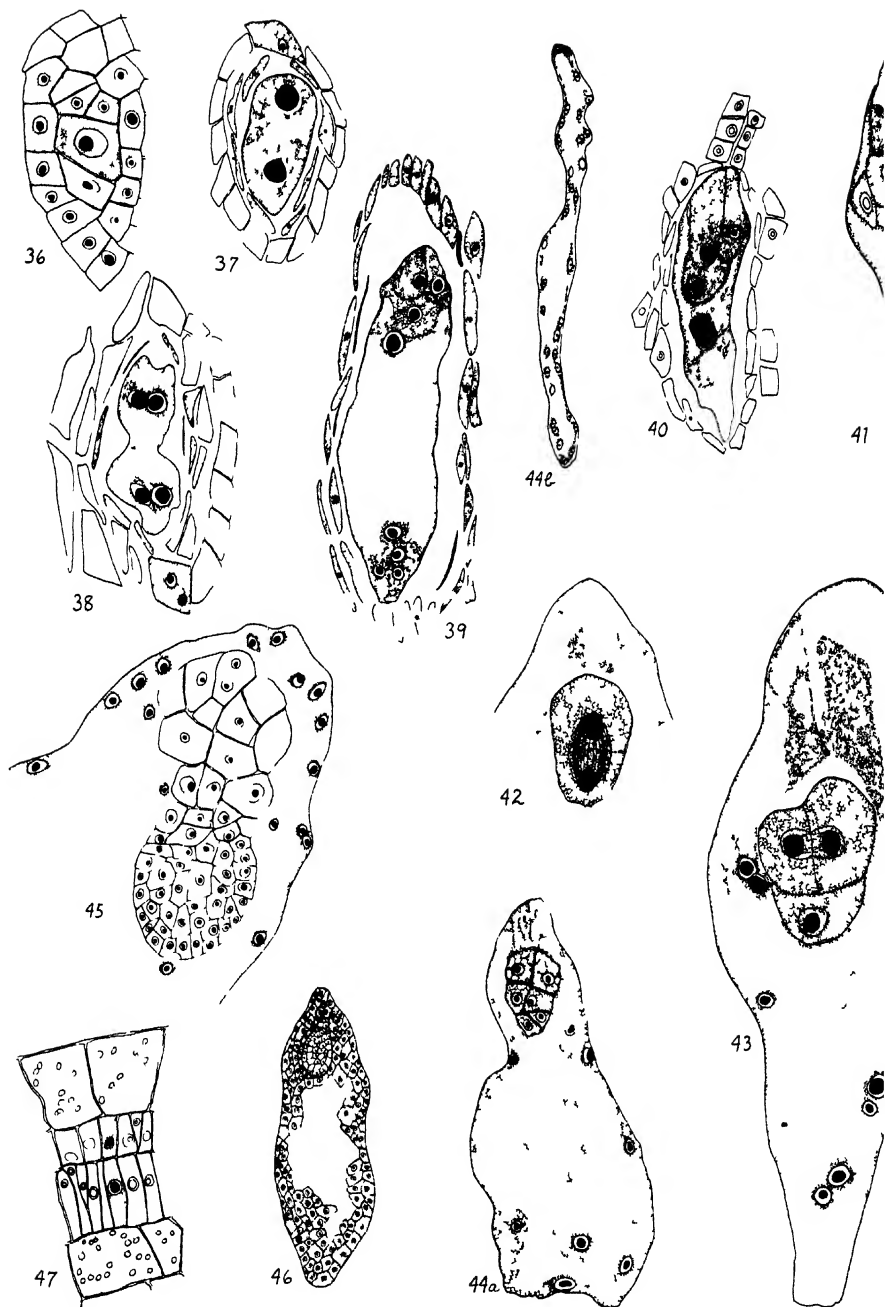




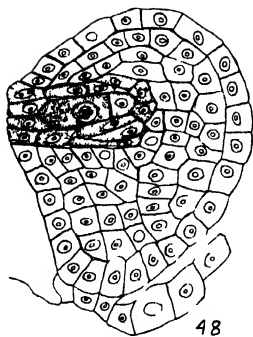
PLATE 29







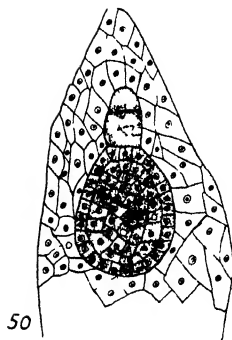
# PLATE 30



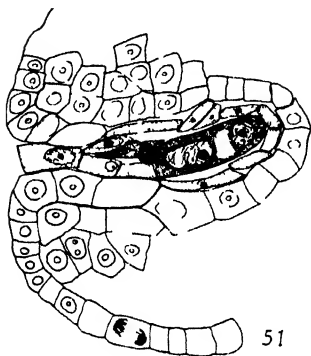
48



49



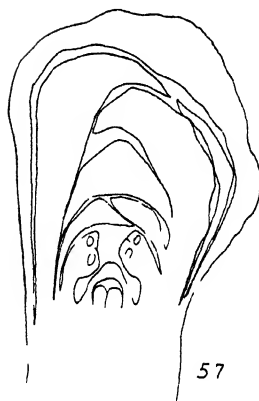
50



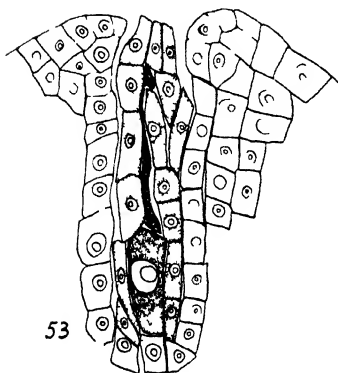
51



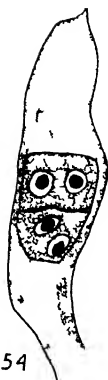
52



57



53



54



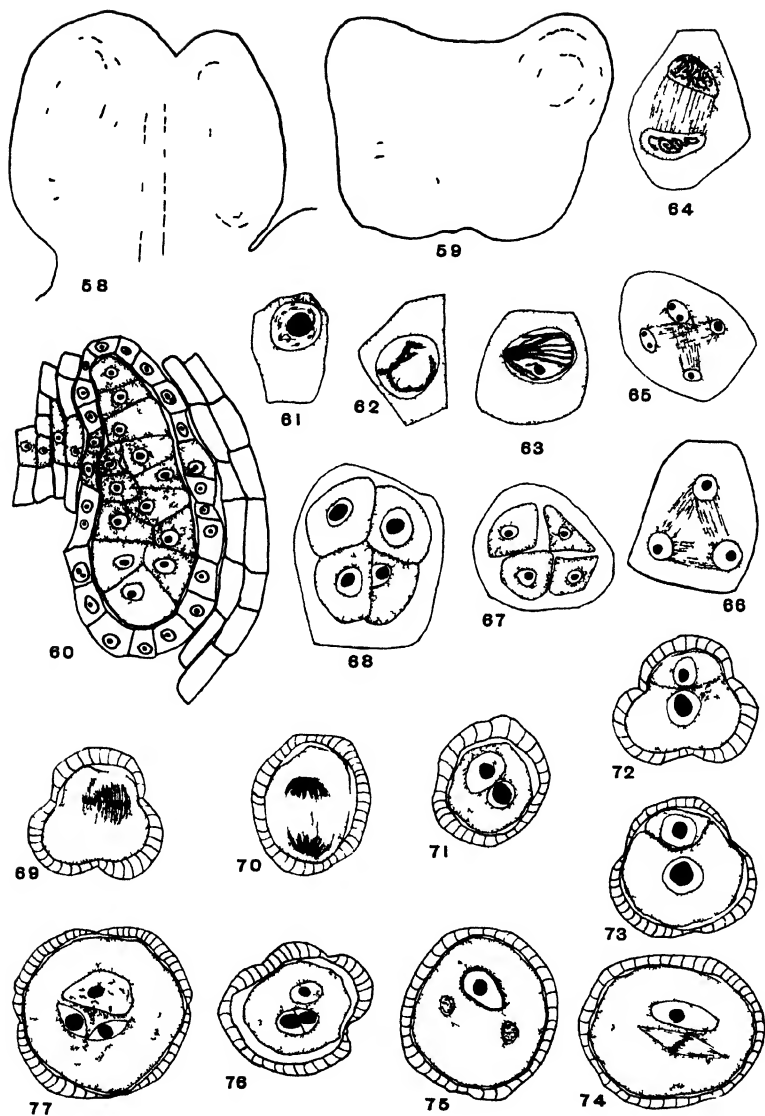
55



56



# PLATE 31





PUBLICATIONS IN THE FIELD OF SCIENCE FROM THE  
UNIVERSITY OF NORTH CAROLINA (1795-1934)\*

Prepared by ALMA HOLLAND

BOTANY

WILLIAM CHAMBERS COKER

B.S., South Carolina Coll., 1894; Ph.D., Johns Hopkins Univ., 1901; Student,  
Univ. of Bonn, Germany, 1901-1902.

Associate Professor of Botany, Univ. of North Carolina, 1902-1907; Professor  
of Botany, 1907-1920; Kenan Professor of Botany and Director of the Arbo-  
retum, 1920- .

- 1902 Notes on the Gametophytes and Embryo of Podocarpus. Bot. Gaz. **33**:  
89-107, pls. 5-7.
- 1903 The Woody Plants of Chapel Hill, N. C. Journ. E. M. Sci. Soc. **19**: 42-49.  
Selected Notes I. Bot. Gaz. **35**: 135-138, figs. 1-6.  
Selected Notes II. Bot. Gaz. **36**: 225-230, figs. 1-5.  
On the Gametophytes and Embryo of Taxodium. Bot. Gaz. **36**: 1-27,  
114-140, pls. 1-11.  
Algae and Fungi for Class Work. Journ. Applied Micros. and Lab. Meth-  
ods **6**: 2411-2412.  
A New Method of Sprouting Pollen Grains. Journ. Applied Micros. and  
Lab. Methods **6**: 2495-2496.
- 1904 Selected Notes III. Bot. Gaz. **37**: 60-63, figs. 1-17.  
On the Spores of Certain Coniferae. Bot. Gaz. **38**: 206-213, figs. 1-24.  
Chapel Hill Liverworts. Journ. E. M. Sci. Soc. **20**: 35-37.  
Angiosperms with Exposed Ovules. (Abst.) Journ. E. M. Sci. Soc. **20**: 117.
- 1905 Observations on the Flora of the Isle of Palms, Charleston, S. C. Torreya  
**5**: 135-145, figs. 1-4. Abst. in Journ. E. M. Sci. Soc. **20**: 12. 1904.

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\* In this bibliography no honorary degrees are listed and no positions except  
those held in the University of North Carolina. We regret that some omissions  
were unavoidable, due to our inability to locate some titles for which only vague  
references were found. Authors are listed only under the department in which  
most of their work was done, but titles representing work in other departments of  
science are included.

- 1905 Vegetation of the Bahama Islands. *In* The Bahama Islands, pp. 185-270, pls. 1 and 33-47. Geographical Society of Baltimore.
- 1906 The Embryo-sac of Liriodendron. (Abst.) Journ. E. M. Sci. Soc. **22**: 59.  
The Endosperm of the Pontederiaceae. (Abst.) Journ. E. M. Sci. Soc. **22**: 61.
- 1907 Fertilization and Embryogeny in *Cephalotaxus fortunei*. Bot. Gaz. **43**: 1-10, pl. 1 and 5 text figs.  
The Development of the Seed in the Pontederiaceae. Bot. Gaz. **44**: 293-301, pl. 23.  
Chapel Hill Ferns and their Allies. Journ. E. M. Sci. Soc. **23**: 134-136. Abst. in **23**: 50.
- 1908 (With J. D. Pemberton) A New Species of Achlya. Bot. Gaz. **45**: 194-196, figs. 1-6. Abst. in Journ. E. M. Sci. Soc. **23**: 48. 1907.  
The Recent Baltimore Meetings of Scientific Societies (Botany Section). Journ. E. M. Sci. Soc. **24**: 155-158
- 1909 A Visit to the Yosemite and the Big Trees. Journ. E. M. Sci. Soc. **25**: 131-143.  
Vitality of Pine Seeds and the Delayed Opening of Cones. Amer. Naturalist **43**: 677-681. Reprinted in Journ. E. M. Sci. Soc. **26**: 43-47, 1910, and abst. in **25**: 47.  
Additions to the Flora of the Carolinas. Bull. Torrey Bot. Club **36**: 635-638. Reprinted in Journ. E. M. Sci. Soc. **25**: 168-171.  
A Double-Flowered Sarracenia. Plant World **12**: 253, 4 figs.  
Liverwort Types for Elementary Classes. Torreya **9**: 233-236, figs. 1-4. Abst. in Journ. E. M. Sci. Soc. **22**: 61. 1906.  
*Lycopodium adpressum* forma *polyclavatum* from South Carolina. Fern Bull. **17**: 83-85.  
Some Rare Abnormalities in Liverworts. The Bryologist **12**: 104-105, 2 figs.  
Leptogorgia from North Carolina. Mycologia **1**: 262-264, pl. 16.
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A Visit to the Grave of Thomas Walter. Journ. E. M. Sci. Soc. **26**: 31-42, pls. 13 and 14.  
Science Teaching. North Carolina High School Bulletin **1**: 35-52.
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Dr. Joseph Hinson Mellichamp. Journ. E. M. Sci. Soc. **27**: 37-64, pl. 6.

- 1911 The Garden of André Michaux. Journ. E. M. Sci. Soc. **27**: pt. 2: 65-72, pls. 1-4.  
 The Plant Life of Hartsville, S. C. Journ. E. M. Sci. Soc. **27**: 169-205, pls. 1-15. Also published in much enlarged form by The Pee Dee Hist. Assoc. 1912.  
 (With Louise Wilson) *Schizosaccharomyces octosporus*. Mycologia **3**: 283-287, pl. 55 and 2 text figs. Abst. in Journ. E. M. Sci. Soc. **27**: 83.  
 Additions to the Flora of the Carolinas—II. Torreya **11**: 9-11.  
 Some Interesting Water Molds. (Abst.) Journ. E. M. Sci. Soc. **27**: 83.
- 1912 The Seedlings of the Live Oak and White Oak. Journ. E. M. Sci. Soc. **28**: 34-41, pls. 2 and 3.  
 (With O. W. Hyman) *Thraustotheca clavata*. Mycologia **4**: 87-90, pl. 63.  
*Achlya deBaryana* Humphrey and the Prolifera Group. Mycologia **4**: 319-324, pl. 78.  
*Achlya glomerata* sp. nov. Mycologia **4**: 325-326, pl. 79.
- 1914 Two New Species of Water Molds. Mycologia **6**: 285-302, pls. 146-148.  
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 The Botanical Society of America. Journ. E. M. Sci. Soc. **29**: 113-115.  
 An Achlya of Hybrid (?) Origin. (Abst.) Journ. E. M. Sci. Soc. **30**: 63.  
 Also in Science **40**: 386.  
 Some Rare Plants and Singular Distributions in North Carolina. (Abst.) Journ. E. M. Sci. Soc. **30**: 66-67. Also in Science **40**: 387.
- 1915 Our Mountain Shrubs. Journ. E. M. Sci. Soc. **31**: 91-112.  
 (With E. O. Randolph) Observations on the Lawns of Chapel Hill. Journ. E. M. Sci. Soc. **31**: 113-119.  
 Winter Grasses of Chapel Hill. Journ. E. M. Sci. Soc. **31**: 156-161.  
 The Lawn Problem in the South. Journ. E. M. Sci. Soc. **31**: 162-165.  
 Abst. in **30**: 67. 1914.  
 The Teaching of Botany in High Schools. North Carolina High School Bull. **6**: 77-79.
- 1916 The Laurel Oak or Darlington Oak (*Quercus laurifolia* Michx.). Journ. E. M. Sci. Soc. **32**: 38-40, pls. 2-5.  
 Some Interesting Mushrooms. (Abst.) Journ. E. M. Sci. Soc. **32**: 46-47.  
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 (With H. R. Totten) The Shrubs and Vines of Chapel Hill. Journ. E. M. Sci. Soc. **33**: 66-81.  
 Our Campus. Alumni Review **4**: 154-155.



- 1916 (With H. R. Totten) The Trees of North Carolina. (106 pp.) Pub. by W. C. Coker, Chapel Hill, N. C.
- 1917 The Amanitas of the Eastern United States. Journ. E. M. Sci. Soc. **33**: 1-88, pls. 1-69.  
*Saprolegnia anisospora* in America. (Abst.) Journ. E. M. Sci. Soc. **33**: 95.
- 1918 The Lactarias of North Carolina. Journ. E. M. Sci. Soc. **34**: 1-62, pls. 1-40.  
A Visit to Smith Island. Journ. E. M. Sci. Soc. **34**: 150-153, pls. 10-16.
- 1919 The Hydnums of North Carolina. Journ. E. M. Sci. Soc. **34**: 163-197, pls. 1-29.  
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A Parasitic Blue-green Alga. (Abst.) Journ. E. M. Sci. Soc. **35**: 9.  
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- 1920 Notes on the Lower Basidiomycetes of North Carolina. Journ. E. M. Sci. Soc. **35**: 113-182, pls. 23 and 30-67.  
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- 1922 (With F. A. Grant) A New Genus of Water Mold Related to Blastocladia. Journ. E. M. Sci. Soc. **37**: 180-182, pl. 32.  
A Visit to Lapland and to Some Old Herbaria. (Abst.) Journ. E. M. Sci. Soc. **38**: 24-25.

- 1922 (With H. C. Beardslee) The Laccarias and Clitocybes of North Carolina. Journ. E. M. Sci. Soc. **38**: 98-126, pls. 1 and 7-33.
- 1923 The Saprolegniaceae. (201 pp., 63 pls.) The University of North Carolina Press, Chapel Hill, N. C.
- The Clavarias of the United States and Canada. (209 pp., 92 pls.) The University of North Carolina Press, Chapel Hill, N. C.
- (With J. N. Couch) The Gasteromycetes of North Carolina [Phalloids]. Journ. E. M. Sci. Soc. **38**: 231-243, pls. 71-83.
- (With J. N. Couch) A New Species of *Thraustotheca*. Journ. E. M. Sci. Soc. **39**: 112-115, pl. 8.
- 1924 (With Enid Matherly) How to Know and Use the Trees. Extension Bull. **3**: No. 14. Pls. 1-39. Chapel Hill, N. C.
- The Geasters of the United States and Canada. Journ. E. M. Sci. Soc. **39**: 170-224, pls. 18-36.
- (With H. C. Beardslee) The Mycenae of North Carolina. Journ. E. M. Sci. Soc. **40**: 49-91, pls. 6-30.
- (With J. N. Couch) Revision of the Genus *Thraustotheca*, with a Description of a New Species. Journ. E. M. Sci. Soc. **40**: 197-202, pls. 38-40.
- 1926 Further Notes on Hydnums. Journ. E. M. Sci. Soc. **41**: 270-287, pls. 51-65.
- (With H. H. Braxton) New Water Molds from the Soil. Journ. E. M. Sci. Soc. **42**: 139-149, pls. 10-15.
- 1927 Other Water Molds from the Soil. Journ. E. M. Sci. Soc. **42**: 207-226, pls. 27-36.
- (With P. M. Patterson) A New Species of *Pythium*. Journ. E. M. Sci. Soc. **42**: 247-250, pl. 46.
- New or Noteworthy Basidiomycetes. Journ. E. M. Sci. Soc. **42**: 251-257, pls. 47-49.
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- Lars Romell. Journ. E. M. Sci. Soc. **43**: 146-151, 1 pl.
- 1928 The Distribution of Venus's Fly Trap (*Dionaea muscipula*). Journ. E. M. Sci. Soc. **43**: 221-228, pl. 33.
- Notes on Basidiomycetes. Journ. E. M. Sci. Soc. **43**: 233-242, frontispiece and pls. 36, 37, 47, 48.
- The Chapel Hill Species of the Genus *Psalliota*. Journ. E. M. Sci. Soc. **43**: 243-256, frontispiece and pls. 38-46 and 48.
- Variation in our Native Ornamental Flowering Trees. (Abst.) Journ. E. M. Sci. Soc. **44**: 19.
- The Limits of Life. (Abst.) Journ. E. M. Sci. Soc. **44**: 48.

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- 1930 The Flora of North Carolina. (Abst.) Journ. E. M. Sci. Soc. **45**: 182-183.  
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- 1932 (With J. S. Holmes and C. F. Korstian) William Willard Ashe. Journ. E. M. Sci. Soc. **48**: 40-47, frontispiece.  
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- 1933 The Opportunities for Botanical Study at the Highlands Laboratory. (Abst.) Journ. E. M. Sci. Soc. **49**: 35.
- 1934 (With H. R. Totten) The Trees of the Southeastern States. (399 pp., 232 drawings, 3 pls.) The University of North Carolina Press, Chapel Hill, N. C.  
The Gasteromycetes of Venezuela. In Carlos E. Chardon: Mycological Explorations of Venezuela, Chap. 20.

#### JOHN NATHANIEL COUCH

B.A., Univ. of North Carolina, 1919; M.A., Ibid., 1922; Ph.D., Ibid., 1924.

Instructor in Botany, Univ. of North Carolina, 1922-1925; Assistant Professor, 1925-1928; Associate Professor, 1928-1932; Professor, 1932-.

- 1920 (With W. C. Coker) A New Species of Achlya. Journ. E. M. Sci. Soc. **36**: 100-101.
- 1922 Science in the High School. A Review of Science Teaching in the High Schools of North Carolina for 1920-1921. The High School Journal **5**: 211-216.
- 1923 (With W. C. Coker) The Gasteromycetes of North Carolina [Phalloids]. Journ. E. M. Sci. Soc. **38**: 231-243, pls. 71-83.  
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- 1924 Some Observations on Spore Formation and Discharge in Leptoglenia, Achlya, and Aphanomyces. Journ. E. M. Sci. Soc. **40**: 27-42, pls. 4 and 5.  
A Dioecious Water Mold (*Dictyuchus monosporus*). (Abst.) Journ. E. M. Sci. Soc. **40**: 116.

- 1924 (With W. C. Coker) Revision of the Genus *Thraustotheca*, with a Description of a New Species. *Journ. E. M. Sci. Soc.* **40**: 197-202, pls. 38-40.
- 1925 A New Dioecious Species of *Choanephora*. *Journ. E. M. Sci. Soc.* **41**: 141-150, pls. 8-11.
- 1926 Heterothallism in *Dictyuchus*, A Genus of the Water Moulds. *Annals of Botany* **40**: 849-881, pls. 35-38 and 3 text figs.
- Notes on the Genus *Aphanomyces*, with a Description of a New Semiparasitic Species. *Journ. E. M. Sci. Soc.* **41**: 213-227, pls. 26-33.
- 1927 Some New Water Fungi from the Soil, with Observations on Spore Formation. *Journ. E. M. Sci. Soc.* **42**: 227-242, pls. 37-43.
- 1928 (With W. C. Coker) The Gasteromycetes of the Eastern United States and Canada. (201 pp., 123 pls.) The University of North Carolina Press, Chapel Hill, N. C.
- 1929 A Monograph of *Septobasidium*.—Part I. Jamaican Species. *Journ. E. M. Sci. Soc.* **44**: 242-260, pls. 10-25.
- 1931 The Biological Relationship between *Septobasidium retiforme* (B. & C.) Pat. and *Aspidiotus osborni* New. and Ckll. *Quart. Journ. Micros. Sci.* **74**: 383-437, pls. 15-19 and 60 text figs.
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- *Micromyces Zygononii* Dang., Parasitic on *Spirogyra*. *Journ. E. M. Sci. Soc.* **46**: 231-239, pls. 16-18.
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- Gametogenesis in *Vaucheria*. *Bot. Gaz.* **94**: 272-296, with 35 text figs.
- The Development of the Sexual Organs in *Leptolegnia caudata*. *Amer. Journ. Bot.* **19**: 584-599, pls. 42-44.
- 1933 Basidia of *Septobasidium (Glenospora) Curtisii*. *Journ. E. M. Sci. Soc.* **49**: 156-162, pls. 10 and 11.
- 1934 New or Little Known Chytridiales. *Mycologia* **27**: (in press).

## JAMES VERNON HARVEY

B.A., Mississippi Coll., 1923; M.A., Univ. of North Carolina, 1925.

Teaching Fellow in Botany, Univ. of North Carolina, 1923-1925.

- 1925 A Study of the Water Molds and Pythiums Occurring in the Soils of Chapel Hill. *Journ. E. M. Sci. Soc.* **41**: 151-164, pls. 12-19. •

## ANDREW CLARK MATHEWS

B.A., Univ. of North Carolina, 1928; M.A., Ibid., 1931.

Teaching Fellow in Botany, Univ. of North Carolina, 1929-1932.

- 1932 Cytological Observations on Zoospore Formation in *Leptolegnia caudata* deBary. Journ. E. M. Sci. Soc. 47: 281-292, pls. 26 and 27.

The Seed Development in *Pinus palustris*. Journ. E. M. Sci. Soc. 48: 101-118, pls. 6-12.

## VELMA DARE MATTHEWS

B.A., North Carolina Coll. for Women, 1925; M.A., Univ. of North Carolina, 1927; Ph.D., Ibid., 1930.

Assistant in Botany, Univ. of North Carolina, 1927-1930, 1931-1934.

- 1928 Nowakowskiella and a New Species of Pythium. Journ. E. M. Sci. Soc. 43: 229-232, pls. 34 and 35.
- 1931 Studies on the Genus Pythium. (136 pp., 29 pls.) The University of North Carolina Press, Chapel Hill, N. C.
- 1932 The Aquatic Vegetation of Quaker Run. Journ. E. M. Sci. Soc. 47: 74-84.

## PAUL MORRISON PATTERSON

B.A., Davidson Coll., 1925; M.A., Univ. of North Carolina, 1927; Ph.D., Johns Hopkins Univ., 1933.

Teaching Fellow in Botany, Univ. of North Carolina, 1925-1926; Instructor, 1926-1927.

- 1927 (With W. C. Coker) A New Species of Pythium. Journ. E. M. Sci. Soc. 42: 247-250, pl. 46.
- Fertilization and Oogenesis in *Achlya colorata*. Journ. E. M. Sci. Soc. 43: 108-123, pls. 8-10.
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- 1928 Our Common Mosses. (Abst.) Journ. E. M. Sci. Soc. 44: 19.

## KENNETH BRYAN RAPEE

B.A., Univ. of North Carolina, 1929.

Assistant in Botany, Univ. of North Carolina, 1926-1929.

- 1928 Studies on the Frequency of Water Molds in the Soil. Journ. E. M. Sci. Soc. 44: 133-139.

## HENRY ROLAND TOTTEN

B.A., Univ. of North Carolina, 1913; M.A., Ibid., 1914; Ph.D., Ibid., 1923; Student at the Univ. of Paris.

Assistant in Botany, Univ. of North Carolina, 1913-1914; Instructor, 1914-1917, 1919-1923; Assistant Professor, 1923-1925; Associate Professor, 1925-1929; Professor, 1929-.

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## CHEMISTRY

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B.S., Univ. of North Carolina, 1892; Ph.D., *Ibid.*, 1894.

Assistant in Chemistry, Univ. of North Carolina, 1891-93; Instructor, 1893-1894; Assistant Professor, 1894-1898; Associate Professor, 1898-1900; Professor, 1900-1904.

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## JAMES MUNSIE BELL

B.A., Univ. of Toronto, 1902; M.A., *Ibid.*, 1905; Ph.D., Cornell Univ., 1905.

Associate Professor of Phys. Chem., Univ. of North Carolina, 1910-1913; Professor Phys. Chem., 1913-1934; Head of the Chem. Dept., 1921-1934; Dean of School of Applied Science, 1929-1934.

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RALPH WALTON BOST

B.A., Newberry Coll., 1923; M.A., Univ. of North Carolina, 1924; Ph.D., Ibid., 1928.

Instructor in Chemistry, Univ. of North Carolina, 1926-1928; Assistant Professor, 1928-.

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## JAMES SCOTT CALLISON

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## FRANK KENNETH CAMERON

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Professor of Chemistry, Univ. of North Carolina, 1926-.

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Assistant in Chemistry, Univ. of North Carolina, 1894-1896, 1898-1899; Instructor, 1899-1900.

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B.S., N. C. State Coll., 1920; M.S., Univ. of North Carolina, 1923; Ph.D., *Ibid.*, 1926.

Teaching Fellow in Chemistry, Univ. of North Carolina, 1921-1922; Instructor, 1922-1926; Assistant Professor, 1926-1930; Associate Professor, 1930-.

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#### ROYAL OSCAR EUGENE DAVIS

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B.A., Univ. of North Carolina, 1882; Ph.D., Ibid., 1885.

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JAMES TALMAGE DOBBINS

B.A., Univ. of North Carolina, 1911; M.A., Ibid., 1912; Ph.D., Ibid., 1914.

Associate Professor of Chemistry, Univ. of North Carolina, 1918-1930; Professor, 1930-.

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Associate Professor of Industrial Chemistry, Univ. of North Carolina, 1921-1928; Professor, 1928-1930.

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Associate Professor of Chemistry, Univ. of North Carolina, 1900-1912; Professor of Organic Chemistry, 1912-.

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Ph B., Univ. of North Carolina, 1883.

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## ADOLPHUS ERWIN WILSON

Student in Univ. of North Carolina, 1882-1885.

- 1885 Analysis of Red Hematite from Forsyth County. Journ. E. M. Sci. Soc. 2: 95.

## JULIAN WOOD

Ph.B., Univ. of North Carolina, 1884.

- 1884 Action of Ammonia Hydrate on Lead Chloride. Journ. E. M. Sci. Soc. 1: 24-26.

## ENGINEERING

## NEIL PHILLIPS BAILEY

B.S., Univ. of Colorado, 1924; M.S., Univ. of Idaho, 1927.

Assistant Professor of Mechanical Engineering, Univ. of North Carolina, 1929-1930; Associate Professor, 1930-1934.

- 1929 Heat flow from underground electric power cables. *Trans. Amer. Inst. Elec. Engineers* 48: 156-165.
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HERMAN GLENN BAITY

B.A., Univ. of North Carolina, 1917; B.S., *Ibid.*, 1922; M.S., Harvard Univ., 1925; Sc.D., *Ibid.*, 1928.

Assistant in Physics, University of North Carolina, 1915-1917; Instructor in Mathematics, 1920-1922; Associate Professor of Sanitary and Munic. Eng'g., 1926-1929; Professor, 1929-; Dean of the School of Eng'g., 1931-.

- 1921 (With A. Henderson) An Interesting Maximal Case. *Journ. E. M. Sci. Soc.* 37: 61-72, pl. 3.
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GUSTAVE MAURICE BRAUNE

B.S., Spring Hill Coll., 1888; Graduate in Civil Eng'g., Royal Polytechnic, Dresden, Saxony, 1895.

Professor of Civil Engineering, Univ. of North Carolina, 1921-1922; Dean of the School of Engineering, 1922-1930.

- 1921 (With Jacob Feld) Large Apparatus for Tests of Lateral Earth Pressures. *Engineering News-Record* 87: 314-316.
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#### WILLIAM CAIN

M.A., North Carolina Military Polytechnic Inst., 1866.

Professor of Mathematics, Univ. of North Carolina, 1889-1918; Kenan Professor, 1918-1920; Kenan Professor Emeritus, 1920-1930.

- 1890 Stability of Loaded Masonry Dams. Discussion. *Trans. Amer. Soc. Civil Engineers* 23: 13-16.
- 1891 Determination of the Stresses in Elastic Systems by the Method of Least Work. *Trans. Amer. Soc. Civil Engineers* 24: 265-308, 1 pl.  
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## PARKER HAYWARD DAGGETT

B.S., Harvard Univ., 1910.

Associate Professor of Electrical Engineering, Univ. of North Carolina, 1910-1913; Professor and Head of the Department, 1913-1929.

- 1911 The Eligibility of "Deceleration." Elect. World 57: 794-795.
- 1917 What Text Shall I Use in General Science? N. C. High School Bull. 8: 122-124.



## THOMAS FELIX HICKERSON

Ph.B., Univ. of North Carolina, 1904; M.A., *Ibid.*, 1907; B.S., Massachusetts Inst. Technology, 1909.

Instructor in Mathematics, Univ. of North Carolina, 1905-1908; Associate Professor of Civil Engineering, 1910-1920; Professor, 1920—.

- 1911 Formulas for Investment Calculations. *Journ. E. M. Sci. Soc.* **27**: 136-152.  
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#### HAROLD FREDERICK JANDA

C.E., Univ. of Wisconsin, 1916.

Associate Professor of Highway Engineering, Univ. of North Carolina, 1921-1926; Professor, 1926-1928.

- 1924 (With C. M. Upham) Removal of Capillary Moisture in Highway Subgrades. *Eng'g. News-Record* **93**: 912-913. Abst. in *Journ. E. M. Sci. Soc.* **40**: 118-119.
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#### JOHN EMERY LEAR

B.S., Virginia Polytechnic Inst., 1901; E.E., Texas Agric. and Mechan. Coll., 1909.

Professor of Engineering Sciences, Univ. of North Carolina, 1918-1923; Professor of Electrical Engineering, 1923—.

- 1920 Construction of Rural Telephone Lines. Univ. N. C. Extension Leaflets 4, No. 2. (20 pp.)
- 1927 Magneto Tachometer Adapted as a Slip-meter. Elect. World 89: 1200.

#### THORNDIKE SAVILLE

B.A., Harvard Univ., 1914; B.S., Dartmouth Coll., 1914; C.E., Ibid., 1915; M.S., Harvard, 1917; M.S., Mass. Inst. Technology, 1917.

Associate Professor of Hydraulic and Sanitary Engineering, Univ. of North Carolina, 1919-1924; Professor, 1924-1932.

- 1919 Sanitation in the South. Univ. N. C. Extension Leaflets 2, No. 9. (26 pp.) (With Carl L. Weir) Sewage-Treatment Works at Langley Field, Virginia. Eng'g. News-Record 83: 374-377.
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#### WILLIAM CAPEHART WALKE

B.S., in Elect. Eng'g., Univ. of North Carolina, 1916.

Engineer for Univ. of North Carolina Extension Division, 1920-1921.

- 1920 Development of Farm Water Powers. Univ. N. C. Extension Leaflets 3, Nos. 9 and 10. (13 pp., 7 figs.)

JOHN DARGAN WATSON

B.A., Furman Univ., 1925; B.S., Univ. of North Carolina, 1928; M.S., Ibid., 1932.

Instructor in Civil Engineering, Univ. of North Carolina, 1930-1934

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B.S.E., Univ. of Michigan, 1925; M.S., Univ. of California, 1926; Sc.D., Univ. of Michigan, 1928.

Associate Professor of Chemical Engineering, Univ. of North Carolina, 1930—

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GEOLOGY

JAMES ATWELL ALEXANDER

B.A., Davidson Coll., 1929; M.A., Ibid., 1931; Graduate student, Univ. of North Carolina, 1931—.

Teaching Fellow in Geology, Univ. of North Carolina, 1931-1934.

- 1933 (With W. F. Prouty and G. R. MacCarthy) Some Magnetometer Observations in the Coastal Plain Area of South Carolina. (Abst.) Journ. E. M. Sci. Soc. 49: 20-21.

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#### JEFFERSON CARNEY BYNUM

B.S., Univ. of North Carolina, 1920; M.S., Ibid., 1926.

Assistant in Geology, Univ. of North Carolina, 1919-1920; Instructor, 1924-1927; Assistant Professor of Geography and Geology, 1927-1932.

- 1928 Piedmont North Carolina and Textile Production. Econ. Geography 4: 232-240.

- 1929 Outline of Work in Geology V. (32 pp.) Chapel Hill, N. C.

#### COLLIER COBB

B.A., Harvard, 1889; M.A., Ibid., 1894.

Assistant Professor of Geology and Mineralogy, Univ. of North Carolina, 1892-1893; Professor 1893-1934; Kenan Professor Emeritus, 1934—.

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Curator of the Geological Museum, Univ. of North Carolina, 1933-1934.

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B.A., Yale Univ., 1813.

Professor of Mathematics and Natural Philosophy, Univ. of North Carolina, 1818-1825; Professor of Chemistry, Mineralogy, and Geology, 1825-1857.

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B.A., Yale Univ., 1813.

Professor of Chemistry and Mineralogy, Univ. of North Carolina, 1818-1824 (elected in 1817); Professor of Chemistry, Mineralogy, and Geology, 1824-1825.

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Instructor in Geology, Univ. of North Carolina, 1912-1917.

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B.A., Johns Hopkins Univ., 1915; Ph.D., *Ibid.*, 1923.

Assistant Professor of Geology, Univ. of North Carolina, 1923-1926; Associate Professor, 1926-1931.

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WILLIAM JACKSON WEAVER

B. Litt., Univ. of North Carolina, 1895; Medical student, *Ibid.*, 1895-1897.

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CHARLES HENRY WHITE

B.S., Univ. of North Carolina, 1894.

Assistant in Physics, Univ. of North Carolina, 1893-1894.

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## MATHEMATICS

## EDWARD TANKARD BROWNE

B.A., Univ. of Virginia, 1915; M.A., *Ibid.*, 1917; Ph.D., Univ. of Chicago, 1926.

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B.S., Citadel, 1919; M.S., Univ. of North Carolina, 1926; Ph.D., Ohio State Univ., 1931.

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1926 Method of Solving Simultaneous Quadratic Equations. (Abst.) *Journ. E. M. Sci. Soc.* **42**: 15.

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## JOSEPH CALDWELL

B.A., Princeton Univ., 1791.

Professor of Mathematics, Univ. of North Carolina, 1796-1804 and 1812-1817; President, 1804-1812 and 1817-1835.

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## RALPH HENRY GRAVES

B.S., C.E., Univ. of Virginia, 1874.

Professor of Engineering (and other Applied Mathematics), Univ. of North Carolina, 1875-1881; Professor of Mathematics, 1881-1889.

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B.A., Univ. of North Carolina, 1898; M.A., *Ibid.*, 1899; Ph.D., *Ibid.*, 1901; Ph.D., Chicago, 1915; Student at Cambridge University, Berlin, and The Sorbonne, 1910-11.

Instructor in Mathematics, Univ. of North Carolina, 1898-1902; Associate Professor, 1903-1908; Professor, 1908-1920; Kenan Professor and Head of the Department, 1920-.

- 1901 The Cone of the Normals and an Allied Cone for Central Surfaces of the Second Degree. (Thesis for Ph.D.) *Journ. E. M. Sci. Soc.* 17, pt. 2: 32-60.

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## ALLAN WILSON HOBBS

B.A., Guilford Coll., 1907; Ph.D., Johns Hopkins Univ., 1917.

Instructor in Mathematics, Univ. of North Carolina, 1917-1919; Assistant Professor, 1919-1920; Associate Professor, 1920-1924; Professor, 1924-; Dean of the Coll. of Liberal Arts, 1930-.

- 1920 *Observations on the Teaching of Algebra. High School Journ.* 3: 14-15.
- 1921 *Einstein's Special Relativity Theory. (Abst.) Journ. E. M. Sci. Soc.* 36: 104.
- 1924 (With Archibald Henderson and J. W. Lasley, Jr.) *The Theory of Relativity, Studies and Contributions.* (99 pp.) The University of North Carolina Press, Chapel Hill, N. C.

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- 1930 (With Archibald Henderson) The Cubic and Biquadratic Equations. Vieta's Transformation in the Complex Plane. Amer. Math. Monthly 37: 515-521.

VINTON ASBURY HOYLE

B.A., Univ. of North Carolina, 1924; M.A., Ibid., 1925; Ph.D., Princeton, 1930.

Fellow in Mathematics, Univ. of North Carolina, 1924-1925; Instructor, 1925-1927; Assistant Professor, 1930—.

- 1931 Some Problems in Conformal Geometry. (30 pp.) Mack Printing Co., Easton, Pa.

JOHN WAYNE LASLEY, JR.

B.A., Univ. of North Carolina, 1910; M.A., Ibid., 1911; Ph.D., Univ. of Chicago, 1920.

Instructor in Mathematics, Univ. of North Carolina, 1911-1915 and 1916-1918; Assistant Professor, 1918-1920; Associate Professor, 1920-1924; Professor, 1924—.

- 1917 Some Elementary Vector Equations. Journ. E. M. Sci. Soc. 32: 143-148.  
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- 1918 Relating Mathematics to Life. High School Journ. 1, No. 4: 20-21.
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#### ERNEST LLOYD MACKIE

B.A., Univ. of North Carolina, 1917; M.A., Harvard, 1920; Ph.D., Chicago, 1927.

Assistant Professor of Mathematics, Univ. of North Carolina, 1921-1926; Associate Professor, 1926—.

- 1928 A Proof of the Jacobi Condition for a Particular Type of Problem. (Abst.) Journ. E. M. Sci. Soc. **44**: 26.
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#### CHARLES PHILLIPS

B.A., Univ. of North Carolina, 1841; M.A., Ibid., 1844.

Tutor in Mathematics, Univ. of North Carolina, 1844-1853; Professor of Civil Engineering, 1853-1860; Professor of Pure Mathematics, 1860-1868, 1875-1879; Professor Emeritus, 1879-1889.

- 1857 A Manual of Plane and Spherical Trigonometry. (200 pp.) Raleigh, N. C. William D. Cooke, pr.



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- 1884 *Astronomical Observatory at the University of North Carolina.* Univ. N. C. Magazine 4 (o.s. 13): Oct., pp. 4-7.

#### JAMES PHILLIPS

Professor of Mathematics and Natural Philosophy, Univ. of North Carolina, 1826-1860; Professor of Mixed Mathematics, 1860-1867.

- 1828 *The Elements of the Conic Sections.* (48 pp., 6 figs.) Pub. by George Long, 161 Broadway, New York.
- 1884 *Meteorological Observations at Chapel Hill, N. C. (1844-1859).* *Journ. E. M. Sci. Soc.* 1: 35-37.
- (With K. P. Battle and R. H. Battle) *Dates of the Flowering of Plants [near Chapel Hill].* *Journ. E. M. Sci. Soc.* 1: 45-46.
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#### MEDICAL SCIENCE

#### FREDERICK PHILLIPS BROOKS

B.S., Univ. of North Carolina, 1921; M.S., *Ibid.*, 1922; Ph.D., *Ibid.*, 1926.

Instructor in Chemistry, University of North Carolina, 1923-1926; Assistant Professor of Biochemistry, 1926-1930; Associate Professor, 1930-1931.

- 1924 (With A. S. Wheeler) *The Action of Phenylsemicarbazide on Acetyl Acetone.* (Abst.) *Journ. E. M. Sci. Soc.* 40: 110-111.
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## WADE HAMPTON BROWN

B.S., Univ. of Nashville, 1899; Student at Univ. of Chicago, 1902-03; M.D., Johns Hopkins, 1907.

Professor of Pathology, Univ. of North Carolina, 1911-1913.

- 1912 Malarial Pigment (Hematin) as a Factor in the Production of the Malarial Paroxysm. *Journ. Exper. Med.* **15**: 579-597. Also in *Journ. E. M. Sci. Soc.* **28**: 97-116.

## JAMES BELL BULLITT

B.A., Washington and Lee, 1894; M.A., Washington and Lee, 1895; M.D., Univ. of Virginia, 1897.

Professor of Pathology, University of North Carolina, 1913-.

- 1920 Report on Autopsies on Twenty-five Cases of Influenza Pneumonia. *Trans. Med. Soc. of the State of North Carolina for 1920*: 18-22. Abst. in *Journ. E. M. Sci. Soc.* **36**: 5-6.
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## DAVID HOUGH DOLLEY

B.A., Randolph-Macon Coll., 1897; M.A., Ibid., 1898; M.D., Johns Hopkins Univ., 1902.

Professor of Microscopic Anatomy and Pathology, Univ. of North Carolina, 1906-1910.

- 1906 (With George Crile) An Experimental Research into the Resuscitation of Dogs Killed by Anaesthetics and Asphyxia. *Journ. Exper. Med.* **8**: 713-725, pls. 42-49.
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WESLEY CRITZ GEORGE

B.A., Univ. of North Carolina, 1911; M.A., *Ibid.*, 1912; Ph.D., *Ibid.*, 1918.

Instructor in Zoology, Univ. of North Carolina, 1912-1916; Associate Professor of Histology and Embryology, 1920-1924; Professor, 1924—.

- 1913 Hybridization Experiments on Frogs. (Abst.) *Science* **37**: 993.
- 1914 Work at the Beaufort Laboratory. *Journ. E. M. Sci. Soc.* **29**: 94-97.
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# RICHARD HENRY LEWIS

M.D., Univ. of Maryland, 1871.

Professor of Diseases of the Eye and Ear, Univ. of North Carolina Medical Department (Raleigh), 1901-1910.

- 1902 The Embalmer in his Relation to Infectious Diseases. Bull. N. C. Bd. Health **17**: 16-20.

- 1906 Presidential Address before Conference of State and Provincial Boards of Health of North America. Bull. N. C. Bd. Health **21**: 25-30.

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# WILLIAM DEBERNIERE MACNIDER

M.D., Univ. of North Carolina, 1903; Student at Chicago and Western Reserve Universities.

Assistant in Biology, Univ. of North Carolina, 1899-1900; Assistant in Anatomy; 1900-1902; Demonstrator of Clinical Pathology, 1902-1905; Professor of Pharmacology and Bacteriology, 1905-1911; Professor of Pharmacology, 1911-1918; Kenan Professor, 1918-1924; Kenan Research Professor, 1924—.

- 1903 (With H. A. Royster) A Case of Ovarian Fibroma. New York Med. Journ. **77**: 4-5. Also in Trans. South. Surg. and Gynecol. Assoc. (for 1902) **15**: 389-393.

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- A Note on the Regeneration of Renal Epithelium in the Intact Cat Kidney. *Journ. Med. Research* **25** (n.s. **20**): 369-372, pl. 5.
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On the Occurrence and Distribution of Potassium in Normal and Nephropathic Kidney Cells. *Proc. Soc. Exper. Biol. and Med.* **13**: 10-12.
- 1916 (With R. L. Payne, Jr.) The Surgical Problem of Unilateral Symptomless Hematuria. *Journ. Amer. Med. Assoc.* **67**: 918-922.  
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Ph.B., Brown Univ., 1919; M.S., *Ibid.*, 1920; Ph.D., Chicago, 1929.

Associate Professor of Bacteriology, Univ. of North Carolina, 1923-1929; Professor, 1929—.

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Student at Univ. of North Carolina, 1882-1886; M.D., Long Island Coll. of Medicine, 1897.

Professor of Physiology in the Medical School, Univ. of North Carolina, 1901—; Dean of the Medical School, 1905-1933.

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B.A., Wake Forest Coll., 1891; M.D., Univ. of Pennsylvania, 1894.

Dean of the Medical School (Raleigh Division) and Professor of Gynecology, Univ. of North Carolina, 1901-1910.

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B.A., Wake Forest Coll., 1886; M.D., Univ. of Virginia, 1887.

Professor of Anatomy and Dean of the Medical School, Univ. of North Carolina, 1889-1905.

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Ph.G., Univ. of North Carolina, 1909.

Instructor in Pharmacy, Univ. of North Carolina, 1909-1913; Assistant Professor, 1913-1917; Associate Professor, 1917-1919; Professor, 1919—; Dean of the School of Pharmacy, 1931—.

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B.A., Wake Forest Coll., 1892; Ph.G., Philadelphia Coll. of Pharmacy, 1894.

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## JOSHUA WALKER GORE

C.E., Univ. of Virginia, 1875; Fellow, Johns Hopkins Univ.

Professor of Natural Philosophy and Engineering, Univ. of North Carolina, 1882-1889; Professor of Natural Philosophy, 1889-1895; Professor of Physics, 1895-1908; Dean of the School of Mining, 1901-1904.

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**JAMES EDWARD LATTA**

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Instructor in Physics, Univ. of North Carolina, 1901-1904; Associate Professor, 1904-1908; Professor of Electrical Eng'g., 1908-1910.

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**ANDREW HENRY PATTERSON**

Ph.B., B.E., Univ. of North Carolina, 1891; B.A., Harvard Univ., 1892; M.A., Ibid., 1893; Student at Berlin, Charlottenburg Technische Hochschule, and Univ. of Cambridge, 1905-1906.

Professor of Physics, Univ. of North Carolina, 1908-1928; Dean of the School of Applied Science, 1911-1928.

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## PSYCHOLOGY

### FLOYD HENRY ALLPORT

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Associate Professor of Psychology, University of North Carolina, 1922-1924.

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Associate Professor of Psychology, University of North Carolina, 1925-1928; Professor, 1928—.

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B.S., Clemson Coll., 1925; M.S., Univ. of North Carolina, 1927.

Teaching Fellow in Psychology, Univ. of North Carolina, 1925-1927.

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B.A., Dartmouth Coll., 1904; M.A., Ibid., 1908; Ph.D., Clark Univ., 1910.

Professor of the Philosophy of Education, Univ. of North Carolina, 1910-1914; Professor of Psychology, 1914-1919; President of the University, 1919-1930.

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JOHN FREDERICK DASHIELL

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### ZOOLOGY

#### GEORGE FRANCIS ATKINSON

Ph.B., Cornell University, 1885.

Assistant Professor of Natural History, Univ. North Carolina, 1885-1887;  
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